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INTRODUCTION

Oklahoma is livestock country, with two-thirds of the total farm income in the state resulting from livestock. It has not always been so. Fifty years ago, only one-third of the state's farm income was attributed to livestock. During the last half-century there has been a gradual shift from the production of cash crops to the production of forage to support the major portion of the state's livestock industry. Today, three-fourths of the state's 44 million acres are utilized to a greater or lesser degree by grazing animals.

Although Oklahoma's livestock industry is predominantly a grazing livestock industry, the non-grazing types will also be mentioned briefly because they do impact directly or indirectly on the total animal industry in the state.

SWINE

The swine industry in Oklahoma was at one time much larger than today. In 1945 the state swine population totaled 1.2 million, compared to 400 thousand today. The nature of the swine industry has also changed, shifting from a family-farm type of production with several sows on each farm, to large, highly specialized operations with several hundred sows each, in confinement or semi-confinement. There is great potential for increased swine production in the state. Oklahoma is a pork deficit state, producing only about one-half of its needs and has several inherent assets such as a mild climate. Consequently, it has been projected that hog numbers in Oklahoma could increase as much as 50% by 1990 and perhaps double by the end of the century.

POULTRY

Many people are surprised to learn that poultry production

ranks 5th in Oklahoma among all agricultural commodities, ranking only behind beef cattle, wheat, dairy cattle and hay. Perhaps one reason is that the poultry industry in Oklahoma is almost totally located in the eastern tier of counties and is not apparent to the casual traveler in many parts of the state. The poultry industry in Oklahoma is primarily one of broiler production; the number of broilers produced in the state increased from 3 million in 1969 to 36 million in 1980.

The nature of the poultry industry has also changed drastically, from one of farm-flock production with some poultry on every farm, to a highly integrated, highly automated industry with relatively few but very large producers.

It has been estimated that by 1990 per capita production of poultry will exceed that of beef, with a demand for 44% more broilers and 34% more layers. Consequently, it is likely that Oklahoma's poultry industry will continue to increase.

HORSES

Oklahoma is horse country! Although not considered food producing animals in the culture of the United States, the many horses in Oklahoma do compete vigorously for available forage and must be considered relative to forage usage.

Changes in horse numbers in Oklahoma have been similar to those of the United States. The national horse herd peaked at 20 million in 1920, decreased to 3 million in 1960, and is expected to reach 20 million again by 1985. There are likely about 500 thousand horses in Oklahoma, with more horses per square mile than in any state in the country.

In 1920 and before horses were used primarily for work and transportation, and only somewhat incidentally for pleasure; today about 97% of the horses are used for pleasure. Although many horses do serve an important role on working cattle ranches in Oklahoma, the majority are used for rodeoing, trail riding, exhibition, youth projects and simply for pleasure riding and as companion animals.

The horse industry in Oklahoma is big business! It has been estimated that each horse generates $1,000 in business for the general economy, which means that in Oklahoma the horse industry is a $500 million business. Now, with the advent of paramutual racing, it is anticipated that the state's horse population will increase further, with a projected increase to 600 thousand by the end of the century if not much sooner.

SHEEP

Sheep numbers in Oklahoma have followed the same pattern as national and even world numbers, with a decrease from 268 thou-

sand in 1940 to 72 thousand in 1977. Since the low point was reached, there has been a gradual increase to 105 thousand in 1982. Because sheep are very complementary to wheat production, more than one-half of the total sheep in Oklahoma are found in the major wheat producing area of north-central Oklahoma. However, they can be produced very satisfactorily throughout the state.

Sheep offer some important advantages. They produce a choice product without grain, produce both food and wool, facilitate optimum range and pasture utilization when grazed with cattle, are adapted to small farms, and perhaps most important have tended to return a profit even in those years when beef cattle production has been unprofitable. However, there are some serious constraints to the expansion of sheep numbers. There is a general lack of knowledge about sheep, and some general sociological constraints in the minds of many people who prefer to produce cattle. Although predators and parasites present fewer problems than in the past, sheep are seasonal breeders, and there is the perennial "vicious circle" of low numbers and low consumption, with the low consumption caused not only by low numbers, but also the high price of lamb. At the present rate of increase, sheep numbers could double in Oklahoma by 1990 and more than quadruple by the end of the century. However, the constraints mentioned above will likely dampen the projected increase in sheep numbers, especially if beef cattle production is at all profitable.

DAIRY CATTLE

Dairy cattle rank as the third most important commodity in Oklahoma agriculture, in spite of the fact that the dairy cow numbers have decreased by 50% during the past 20 years. However, as is true nationally, the great increase in production per cow has allowed the maintenance of a stable milk supply with a considerably lower dairy cow population. In addition, dairy production units have become much larger and more specialized; the average milk produced per farm in Oklahoma doubled from 560 thousand in 1960 to 1.2 million pounds in 1980.

The very high level of milk production per cow found in some herds today is a vivid testimony to the development and application of technology, particularly in the areas of nutrition, progeny testing and artificial insemination.

A need for 35-40% more milk has been projected by the year 2000. In that event, recognizing Oklahoma's inherent advantages of a relatively mild climate and a geographical location close to the sunbelt areas of high population growth, the dairy cattle industry will increase in Oklahoma.

BEEF CATTLE

Oklahoma is obviously beef cattle country, a situation which has developed over the past 60 years:

YEAR	CASH RECEIPTS FROM CATTLE & CALVES, %
1929	14
1949	25
1963	41
1980	56

More specifically, Oklahoma is beef cow country. Again, the increase over the past 60 years has been very dramatic, from 200 thousand cows in 1920 to 2.3 million in 1980. Today, there are more beef cows per square mile in Oklahoma than in any state. There is also a significant cattle feeding industry in Oklahoma, largely centered in the Panhandle, where almost 600 thousand head are fed each year.

The nature as well as the size of the beef cattle industry in Oklahoma has changed markedly in the past 100 years, from the time of the Longhorn cattle (in some respects we have come "full circle" because today Longhorn bulls are being frequently used on first-calf heifers to minimize calving problems). Until about 1950 commercial beef cattle production in Oklahoma consisted largely of straight-bred British breeds which had been bred up from the original Longhorn base. However, as knowledge developed about the benefits of heterosis, producers began crossbreeding and today the majority of calves coming to market are crossbreds, and often carry some blood of the continental breeds which for the most part were imported about 1970. In very recent years we have seen Brahman cattle moving northward in Oklahoma from the breed's traditional stronghold in the southeastern part of the state.

OTHER CHARACTERISTICS OF OKLAHOMA'S LIVESTOCK INDUSTRY

At least three additional traits help to characterize the livestock industry in Oklahoma.

Seed Stock Industry

Oklahoma has historically been important in the genetic improvement and seed stock production of livestock, in some cases far out of proportion to the importance of the commercial industry in the state. In the case of beef cattle, of course, it is no surprise that Oklahoma ranks in the top five in the production of purebred beef cattle in seven breeds, with four additional breeds ranking in the top nine. Likewise, it is not surprising that three separate breeds of horses rank in the top three nationally. It is a bit surprising, however, to find that Oklahoma has six breeds of hogs ranking anywhere from fourth to ninth nationally and similarly, three breeds of sheep ranking

fourth and another breed 7th.

Performance Testing

Many of Oklahoma's seed stock producers were pioneers in performance testing. That emphasis on genetic improvement in traits of economic importance is still evident today, with a central boar test station and central bull test station among the largest and most prominent in the country. For example, approximately 700 bulls are tested each year at the Oklahoma Beef, Incorporated facility at Stillwater alone. Oklahoma seed stock producers and Oklahoma State University have a somewhat unique arrangement wherein the University provides land on a long-term lease basis plus supervision, and the breeders provide the facilities and all costs of the performance testing.

Youth Livestock Projects

Oklahoma has historically placed heavy emphasis on youth livestock projects, including 4-H and FFA involvement in livestock shows. The spring Junior Livestock Show in Oklahoma City, for example, is billed as the largest junior livestock show in the country. Some people are critical of shows, and there are ways in which they could be improved, but among other assets they serve to maintain the interest of young people in animal agriculture. The contention that young people will not be able to adapt to "real life situations" due to the impracticality of livestock shows is without foundation. Young people are very astute and are able to maintain their perspective and consequently have no problem in adapting to commercial livestock production at the appropriate time. Actually, the most prominent carry-over from show involvement is that the young people tend to transfer the desire to excel to livestock production.

THE FUTURE OF THE LIVESTOCK INDUSTRY

Everyone agrees that animal agriculture in the future faces some constraints which are largely applicable nationally and which include at least the following:

1. High production costs
2. Low profits
3. Misinformation (about animal foods)
4. Decreased demand for animal foods
5. Animal rights (and welfare) issue
6. Regulations
7. Waste management

On the other hand, there are some real opportunities ahead in animal agriculture:

1. Demand for food
2. Technology
3. Domestic markets
4. Foreign markets
5. Producing to meet demand

6. Geographic location
7. Climate

Again, most of the opportunities apply nationally, with only the last two being primarily applicable to Oklahoma. (Oklahoma's advantages are likely offset by other advantages in other areas of the country.)

There will be a great increase in demand for food by the end of the century, which obviously bodes well for animal agriculture. By the year 2000 there will be a need for 75% more milk, 80% more beef and 90% more sheep and goats.

Technology represents the most important opportunity over which the individual producer has control. For example, considerable research in Oklahoma and elsewhere has shown that with existing technology most forage-producing operations could double, or even triple and yes, even quadruple forage production, given adequate economic reward. Or, on the animal side, research has shown that beef production can be increased 10% through the use of two-breed crossbreeding, 20% through the use of three-breed crossbreeding, 30% if Brahman are included in the crossbreeding program, 40% if a growthy breed is included in the crossbreeding program, and 50% if a heavy milking breed is included. The list could go on and on.

As we look ahead, we would agree that "we ain't seen nothing yet" when we think of opportunities which have been projected through the use of new technology in such areas as genetic engineering.

KEYS TO SURVIVAL

What does the producer need to do as he looks ahead, to strengthen his operation, and indeed just to survive? He needs to do two things: First, he needs to adopt all available technology that is applicable and profitable in his operation. It is rather revealing to consider the rates of technology adoption in various animal industries.

Industry	Percentage of Technology Adopted
Poultry	90
Dairy	75
Swine	75
Beef Cattle	40-50
Sheep	40-50

These figures certainly provide a vivid explanation of the past and certainly provide some warnings for the future. It is quite apparent that the rate of technology adoption must be increased with our forage producing animals.

Second, the producer must become involved. Historically, the livestock producer has been a rugged individualist, and has been proud of it. This has been commendable but the livestock producers of the future cannot afford such luxury. They must unite to solve problems, such as those relating to market development, public relations and orientation of decision-makers (political impact).

CHALLENGE OF ANIMAL AGRICULTURE

Although this applies more to Oklahoma than some areas, we have two challenges in terms of the agriculture economy. One is to revitalize the beef cattle sector, primarily through the application of existing technology and the development of new technology as possible and necessary. Second is to diversify animal agriculture through the enhancement and growth of such areas as dairy, poultry, swine, sheep and perhaps even in some cases, horses. We have, in Oklahoma, essentially a two-commodity agriculture (beef cattle and wheat), and in those years when prices of beef cattle and wheat are both depressed, the economy of the state suffers.

OKLAHOMA STATE UNIVERSITY'S ROLE

What do we at Oklahoma State University intend to do about the constraints, the opportunities and the challenges relating to animal agriculture? We intend to do three things essentially: (1) Through research we will develop more technology. The difficult questions ahead will require both more research and more sophisticated research, both applied and basic research, and both biological and economic research. (2) We will become more effective in our extension programming to facilitate a higher rate of technology adoption, through such innovations as educational TV, satellite communications, continuing education, expanded use of total mass media, and home video courses just to mention a few possibilities. (3) In our teaching programs we will need to "produce" more graduates to meet the increasing needs of high technology production in many areas of the livestock industry and related agribusiness, and we will need to do a better job of training the students through emphasis not only on the art and science of livestock production, but on the business aspect as well.

Productivity in animal agriculture in terms of output per female (cow, sow, ewe) approximately doubled during the 50 years beginning in 1925. This was largely due to the cooperative efforts of our system of research and education, the hard working livestock producer and an effective agribusiness complex. With the same kind of team work in the future, we have every reason to think that we can more than double productivity per unit in the next fifty years.

PASTURE-LIVESTOCK MANAGEMENT SYSTEMS

W. E. McMurphy

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Precipitation is a controlling factor in the forage production in Oklahoma. The eastern one third of the state has an annual precipitation of over 40 inches and will produce an abundance of forage, both cool and warm season. The western one third of Oklahoma receives about one half the annual precipitation that eastern Oklahoma receives, but the distribution of moisture strongly favors warm season species. Average monthly precipitation is about one inch from November through March, five months. The small grains with mostly wheat pasture are the only viable cool season forages for this western area.

Fescue toxicosis has not been a big problem in Oklahoma, possibly because not enough fescue is grown. Tall fescue is the only cool season perennial grass reasonably well adapted to eastern Oklahoma. However, tall fescue is unreliable as a source of winter forage. No fall growth was produced in four of six years in a study near Pawhuska. Ranchers are thus unwilling to purchase necessary N fertilizer for fall growth for an unreliable situation.

The rough rocky wooded lands of the Ouachita and Ozark Highlands Resource Areas that currently produce blackjack and post oak have great forage potential. Herbicides will control the woody species. Burning will prepare a seedbed for tall fescue. Aerial application of seed and fertilizer have been proven techniques in developing this potential. Unfortunately the economics of this practice are not practical at the present time.

Arrowleaf clover is not the major pasture legume of eastern Oklahoma. This species has three important characteristics vital to its success: (1) it is a prolific reseeding annual, (2) it has hard dormant seed, and (3) it grows tall. Perennial pasture legumes often die during summer drought. The hard

dormant seed characteristic provides seed for another crop when early fall precipitation causes germination followed by drought which can be lethal to all seedlings. The tall growth characteristic enables it to survive spring grazing mismanagement if grasses get too tall. Other pasture legumes in use are hop clover, red clover, white clover, crimson clover, and subterranian clover.

Bermudagrass is the most important introduced grass and occupies at least six million acres. Many of the pastures in eastern Oklahoma that are dominated by broomsedge and weeds appear to be rangeland because that is the way they are being managed. However, these areas that have bermudagrass present can be quickly converted to very productive pasture. Mowing in early June removes the dormant cool season annual grasses and controls many broadleaf weeds. Then an application of N fertilizer plus P and K fertilizer if needed will quickly convert these seemingly low productive lands into bermudagrass pastures within a month.

Winter hardiness has always been a problem with any new bermudagrass varieties. The Midland and Hardie varieties are the best adapted ones for Oklahoma. A five-year grazing test with steers at Perkins, Oklahoma compared Midland and Hardie bermudagrass. A three paddock rotation was used with the objective to graze grass that was between two and three weeks of age. A split application of N fertilizer was used with 50 lb of N per acre applied three times each season. Average daily gain was 1.80 lb for Hardie and 1.61 lb for Midland. Stocking rates were adjusted with the put and take method to use available forage and averaged 2.4 steers per acre for Hardie and 2.3 steers per acre for Midland. Total beef production per acre was 636 lb for Hardie and 492 lb for Midland. The value of an improved variety was apparent.

Native range that dominates the grassland resources of Oklahoma requires a different management philosophy than that of most introduced grass pastures. The goal of range management for cattle production is to promote plant succession to the point of the tallest climax native grasses the site will support. The goal of pasture management is to prevent plant succession. Plant succession in rangeland is promoted best by permitting the grasses to grow, preferably all during the growing season with grazing done in the dormant season. This deferment when combined with herbicides or fire in special situations is very effective in promoting plant succession. With season long grazing on range, the rule of "take half and leave half" must be followed. It is very necessary to practice this moderate use of range during the growing season to maintain the necessary root carbohydrate reserves for plant vigor and competitive ability. However, these practices do not apply to introduced pasture species and would be a wasted effort. We prevent plant succession in bermudagrass pastures by mowing and fertilizing,

followed shortly by grazing. On rangeland the practices of mowing, fertilizing, then grazing would be disastrous to the native climax grasses.

The range manager must be concerned with adjusting the stocking rate, time of grazing, and degree of use, because he has little control over the quantity of forage production. Stocking rate flexibility is necessary. The pasture manager can adjust the quantity of forage produced with N fertilizer and has more control over timing of that production through selection of species planted and timing of the fertilizer application.

Native range grasses have a slow rate of physiological maturity, and grasses deferred from grazing from May 1 to July 1 are still good quality forage. This is not true of the introduced forage species because they have a much faster rate of physiological maturity with the corresponding decline in forage quality.

The native tall grasses of the True Prairie region have very slow regrowth following herbage removal after July 1. This is the result of evolutionary selection pressures. These species are very palatable, they evolved with grazing, and slow regrowth is a survival mechanism. There is a vast genetic diversity within these tall grass species, but any ecotype which evolved which had rapid regrowth would have been vulnerable. Rapid regrowth occurs at the expense of the root carbohydrate reserves, regrowth is very palatable to herbivores, and such ecotypes probably disappeared from the ecosystem. With such slow regrowth the native ranges will require a much longer period of deferment in a rotation system than the introduced grasses.

The pasture systems of Oklahoma are combined with the native range resource throughout the state. Management of each requires different techniques, but the greatest potential for expansion is with introduced forage species. The technology is available, but the present economical pressures upon the beef industry limit its expansion in Oklahoma.

FORAGE RESOURCES OF OKLAHOMA

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Oklahoma State University

I appreciate the opportunity to present an overview of the plant resources of Oklahoma. Since it is difficult to talk about plants without discussing water and soil I would like to mention these resources also.

The growing of plants for food, fiber, feed, fuel, conservation, recreation, and esthetics is big business in Oklahoma. Plant agriculture is important not only as a livelihood for our farmers and ranchers but also for the well-being of our citizens. We still consider ourselves an agricultural state. However, the climate in Oklahoma is harsh for plant production. Rainfall and temperature vary quite widely across the state and the distribution at any one locality is highly uneven from year to year. Unseasonable cool temperature, frost, or hot dessicating winds frequently reduce plant growth and crop yields.

The extensive types of crop and livestock production have dominated agricultural enterprises in Oklahoma since settlement (as contrasted to intensive). This type of production was best suited to the state's resources and climate. Forage production kept pace with the growing livestock industry. Oklahoma soil and climatic conditions coupled with the intense interest in livestock makes forage production well suited to the state. The land devoted to ranges, pastures, and forage crops exceeds land devoted to cultivated crops by a wide margin. The acreage in improved pasture has quadrupled in the last 25 years. An increase in forage production is anticipated - primarily through improved pasture and range management and the conversion of some ranges into improved pastures.

Water. Certainly one element necessary for successful forage production is water. The sources of water for both livestock and man in Oklahoma include farm ponds, large reservoirs, flood water detention reservoirs, and major streams such as the

Arkansas, Cimarron, Canadian, and Red Rivers and their tributaries. In addition a few of our counties have underground water resources from the Oogalala water formation.

We have over 100,000 farm ponds in Oklahoma. There are 13 large reservoirs throughout the state but most of the water in these is not available for agriculture use. Our annual precipitation varies from about 52 inches in the southeast to 16 inches in the northwest corner of our High Plains. Almost one million acres in Oklahoma is irrigated each year, but this is primarily not on forages. There are exceptions to this as some alfalfa and bermudagrass are irrigated. Most of the water goes for irrigated crops such as cotton, peanuts, soybeans, wheat, and sorghum.

Soils. There are about 44 million acres of land in Oklahoma. Our soils vary widely in the nature of their parent material, their topography, their age, and properties such as organic matter, pH, and cation status. In general organic matter content is low - in the area of 1% or less. Soil pH in most of the state is on the neutral or basic side, but does become acidic as you get into the higher rainfall areas in eastern Oklahoma.

The state is roughly divided into nine resource areas. Of course there are many different soil series within each resource area. Starting from the east the Ouachita Highlands in southeastern Oklahoma is characterized by a series of parallel ridges running generally east and west. The rugged surface and sizable acreages of stoney, shallow soils are developed from weathering of sandstone and shale. This resource area contains nearly a half million acres in pasture and rangeland in Classes I through IV and even more in Classes V through VI.

The Ozark Highlands in northeastern Oklahoma also has a variable surface relief and comprises about 1.6 million acres. Pasture and range make up only about 14% of this area. When we get into the northeast and southeastern corners of the state there are about 2½ million acres of rangeland in these mountainous areas. The average stocking rate in this area is about 40 acres per animal unit (AUY).

The Forested Coastal Plains consist of about one and one-third million acres in southcentral Oklahoma. Most of these soils are sandy and are developed from beds of unconsolidated sands, clays and sandy clays. Pasture and range make up about 15% of this area.

The Cherokee Prairies consist of 6½ million acres of gentle and somewhat rolling land in eastcentral and northeastern Oklahoma. The annual precipitation varies from 35 to 45 inches per year. Low ridges of outcropping sandstone traverse the area and these soils are generally sandy, shallow, and non-arable . The

Bluestem Hills (Flint Hills) are included in the northwest part of this resource area. Pasture and range comprise over half of the acreage in this area. In these eastern prairies we find that the tall grasses are dominant - including switchgrass, Indiangrass, and the big and little bluestems. The ranges of this area (about 1.5 million acres) support an average stocking rate of 10 AUY. This area offers tremendous possibility of expanded forage production.

The Cross Timbers comprise another six million acres through the central part of Oklahoma. The surface relief varies from gently rolling to hilly. The dominant soils are sandstone derived and under natural conditions support mainly a post oak and blackjack oak savannah type of vegetation. Soil is very shallow and has a lower stocking rate than some of the western lands, approximately 45 AUY. The species prevalent in this 2.2 million acres of range area are primarily Indiangrass and the bluestems. The Cross Timber area is rapidly going to improved pasture and we hope to see this trend continue.

The Grand Prairie in southern Oklahoma contains almost two million acres. The surface relief ranges from gently wavey to rolling and hilly. The soils were developed from limestone on shale under the cover of tall grasses. The soils are predominately dark colored and heavy or clayey. About 70% of this area is in pasture and range and forage production can be improved considerably.

The Reddish Prairie in westcentral Oklahoma occupies a wide belt through the state and contains about 8½ million acres of wavey to gently rolling surface relief. The soils developed under a grass cover over weakly calcareous red shales and sandstones. This area has the highest concentration of cultivated cropland in the state, but still about 1/2 of it is devoted to pasture and range. In the Red Prairies there are about 2.3 million acres of range which has primarily big bluestem, side oats gramma, and little bluestem and a stocking rate of about 20 AUY.

The Rolling Red Plains make up a large resource area of about 9½ million acres in the western part of the state. Like the rest of the state it tilts toward the southeast with elevation ranging from 1000 feet in the east to 3000 feet above sea level in the west. The surface is rolling with deep cut valleys and narrow strips of alluvial soils. Most of the 20 to 30 inches of precipitation occurs between April and September, but the distribution is irregular and droughts are common. About four million acres is in pasture and range and comprising primarily of sand and big bluestem, blue gramma, and little bluestem. Here the average stocking rate is about 30 AUY.

The High Plains contain almost four million acres of land sloping from the southeast to a high point in the northwest almost 5000 feet above sea level. The rainfall is only 15 to 20

inches per year. These soils developed from outwash material imported from the higher elevations of the west. On the High Plains we find that the dominant forage species are blue gramma, buffalograss and little bluestem. The range area comprises about 1½ million acres and has a stocking rate of about 40 AUY.

Rangeland. Rangeland and forest range occupy about 20 million acres, or almost one-half of the land area in Oklahoma. It includes all lands on which the native vegetation is predominately grasses, grass-like plants, forbes or shrubs suitable for grazing or browsing. These include land revegetated naturally or artificially to provide a forage cover that is managed like native vegetation. Rangelands in Oklahoma include natural grasslands, hay meadows, savannahs, shrub lands, abandoned cropland and areas originally planted to introduce pasture species but which have reverted to predominately native vegetation because of a lack of proper management. Rangelands may also include many forest lands and grazable woodlands in Oklahoma.

The Oklahoma resouces inventory indicates that about 65% of the rangeland in Oklahoma needs some type of conservation treatment to restore the land to its full potential. The primary needs are for brush and weed control, grazing management and other range improvement practices which increase range condition, herbaceous plant production and groundcover.

The role of rangeland in the Oklahoma economy is difficult to measure because aggregate production data concerning livestock and other uses of rangeland are not available. However, existing knowledge and technology applicable to Oklahoma rangeland could easily double current livestock and wildlife production if implemented thoughout the state. Too often the focus has been on range improvements as a cure for improper grazing management.

Pests. Pests on Oklahoma rangeland include primarily weeds, brush, and insects. There are undesirable plants on most of the 20 million acres of rangeland and forest range. About 11 million of these acres have a serious woody plant problem. These plants are considered undesirable since they are not utilized by livestock and compete with desirable plants. The primary weed problems on rangelands and pastures are broomweeds, ironweeds, and the ragweeds. In the western half of the state the problem is dominated by western ragweed and the broomweed. In the eastern half the problem is dominated by western ragweed and lance-leaf ragweed. Both the common broomweed and the lance-leaf ragweed are annuals, and are particularly a problem following drought years. Most areas are overgrazed during periods of low production and this allows open spaces for the annuals to germinate and establish. Western ragweed is a perennial that spreads both by seed and vegetative underground stems. Once the plants become established the problem tends to increase each year.

Most of the herbaceous plants have about the same requirement for growth as the native desirable plants so that there is about one pound of desirable forage loss for every pound of weeds produced. Weed production on pastures and range varies considerably throughout the state but about 1000 pounds of weeds produced is very common and 2000 pounds is not uncommon. There are normally three control options for taking care of herbaceous weeds on our forage lands. Grazing is one option that is often overlooked. It can be very effective and an economical alternative. It does require heavy stocking rates for a short period of time when the weeds are palatable and then removing the cattle to allow regrowth of desirable grasses. Fair results have been obtained with prairie threeawn, broomsage, sandbur, and western ragweed but results with other species such as western ironweed and common broomweed have been poor.

A second option for controlling weeds is mowing, but it is primarily a cosmetic option the way that mowers use it. Although it can be effective in preventing weeds from producing seed most of the competition has already resulted. There is also loss of desirable forage from mowing. Burning can best replace mowing if done properly. The third and probably best all around option is the use of herbicides to control weeds. The primary herbicide use for weed control is 2,4-D-which is effective on many of the broadleaved weeds and is available in a number of formulations. Dicamba has been mixed with 2,4-D for specific weed problems. Atrazine is also approved for use on rangelands. Its primary advantage is its activity on annual grasses such as the annual bromes and prairie threeawn. Rainfall after application is necessary to move the atrazine into the root zone.

The primary brush problems on the rangelands and pastures of Oklahoma are the scrub oaks. This ranges from the blackjack and post oak complex as the dominant vegetation on the sandy soils of the Cross Timbers and in southeastern Oklahoma to the shinnery oak-sand sage complex which is the dominant vegetation on sandy soils in the western part of the state. Native grass production on some of these areas is less than 500 lbs. per acre. Brush is constantly invading the Oklahoma grasslands since environmental conditions are favorable for brush. It is estimated that there are more acres of rangeland infested with brush now than at any time since statehood. Much of this is attributed to a large increase in eastern red cedar. Some ten years ago this was a problem on about one million acres, but today they are becoming a problem on more than 4½ million acres of the Cross Timbers and Reddish Prairie lands. This increase is attributed to the lack of burning coupled with a large number of seed trees scattered throughout the state. In addition the major brush herbicides do not control eastern red cedar.

Brush control options are available but limited. Mechanical clearing has become very expensive and most desirable sites have

already been converted. The requirement that these sites be "farmed" for two seasons to control resprouts puts a severe limitation on this option. Mowing is possible on level areas but is non-effective on most woody species, with the possible exception of small eastern red cedar trees. In fact mowing will often increase the number of stems of some species. There is also a decrease in top to root ratio and this results in less effective control with any follow up foliar sprays. Burning has essentially the same limitation as mowing. However both mowing and burning can be effective on trees that don't resprout. In fact burning may be the only economical control option available for cedar control.

Herbicides are the most selective and in most cases the most economical brush control option available. The major limitation is that there are currently only a few herbicides that have label clearances for use on rangeland. For 35 years 2,4,5-T has been the major chemical but its economic advantage may be coming to an end. As recently as 1970 a standard application would cost only \$6 to \$7 per acre. However, the cost has tripled in the last 10 years. For many of the oaks treatments for two consecutive years are needed - which also drastically increases the cost. Graslan first received label clearance in Oklahoma and Texas in 1979. It has proven to be an excellent herbicide for blackjack oak, post oak, and winged elm control on shallow sandy soils. However, it is very expensive to use, particularly when one considers the current cattle prices since it takes at least eight acres of brush converted rangeland to provide enough forage for one cow per year.

The amount of grass release after spraying depends on the amount of desirable grass in the treated area, the amount of brush control, the productivity of the site and the amount of effective moisture available for plant growth. The highest yield of grass obtained two or three years after spraying for brush control was about 4000 pounds per acre and this represented a four-fold increase in grass production. The actual advantage of brush control on range usually results in enough increased grass production to allow a doubling of the carrying capacity in addition to an increase in the calving percent and the weaning weight of calves.

Several problems confront range managers and scientists who are attempting to meet the separate demands of ranchers and society. Since rangelands inherently have a low production protential and there is great variability associated with the weather in the range area the capital investment requires long periods for benefits to be realized, and are usually not cost effective when capital costs are high. Higher producing rangelands still continue to occasionally be converted to cropland and other land uses while marginal croplands are being allowed to revert to rangeland. Increases in the densities and the encroachment of brush species on rangeland reduces their production potential

and yet cost effective environmentally acceptable methods of controlling brush are not generally available for use. Extensive management systems are generally called for on rangeland but are often overlooked or ignored because they usually do not result in immediate or sizable increases in production.

Pastures and Forages. Approximately 8.5 million acres in the state are devoted to pasture, hay, and other tame forage production. Forage in this state provides 80% of the nutrients for beef production and 65% of the nutrients for milk production. Beef production in Oklahoma has more than doubled in the past 20 years because slaughter weights have remained relatively constant and cattle in feed lots have less than doubled during this period. Beef production from rangeland and forages has more than doubled. Significant gains in productivity played a major role in the total increase in forage production. The average yield for all hay increased from 1.45 tons per acre in 1958 to 2.12 tons per acre in 1979. Similar productivity gains have been realized for pastures.

A number of factors have enabled Oklahoma farmers and ranchers to increase productivity. Development and utilization of more productive grass varieties and introduction of commercial fertilizers contributed to the increased production for pastures. On-going research in these areas as well as renewed efforts and variety improvement will contribute to production in the future. A number of grass varieties introduced by the Oklahoma Agricultural Experiment Station has significantly raised pasture productivity in the State. Notable varieties include Midland bermudagrass (1953), Morpa lovegrass (1969), Plains bluestem (1970), and Hardie bermudagrass (1974). Most recently Brazos bermudagrass, WW Spar bluestem, and Guymon bermudagrass have been released by various agencies at least partially as the result of the efforts by Oklahoma grass breeders.

Introduced warm and cool season annual and perennial grasses are used extensively in Oklahoma either to supplant or supplement native vegetation. The principle introduced annual grasses used for pasture or forage are the cool season cereals (particularly wheat), the warm season sorghum, and the millets.

A significant portion of the winter wheat seeded in Oklahoma each year is grazed by livestock. Wheat pasture provides a significant forage support to the beef cattle industry of the state. However, gains of wheat pasture stockers are frequently reduced by 1) inadequate fall or winter forage and 2) snow or ice cover of wheat pasture. Stability of the wheat pasture stocker enterprise could be increased by improved agronomic practices such as earlier planting dates to increase the amount of fall and winter forage. While planting dates are influenced by climatic conditions the optimal seeding date for grain production (early October) is too late for production of fall

forage for winter grazing. However, the extreme variability of Oklahoma's climate often will not permit early planting or provide sufficient winter rainfall for best forage production - which increases the risk factor in buying stocker cattle. Because of the large amount of the wheat forage that is produced in the spring there is some potential for increasing gains by extending the grazing period beyond the traditional March 10-15 cut-off date if grain is to be harvested.

The principle introduced perennial grasses used in the state are bermudagrass, weeping lovegrass, yellow bluestem, and tall fescue. The annual and perennial species are often distinguished on the basis of their cultural requirement by the terms cultivated forages and tame pastures respectively. The annual warm season grasses have high productivity capability and the forage is of intermediate nutritive value. The major constraints associated with their use include high production costs, insect and disease pests, and in the case of the sorghum species the potential for hydrocyanic acid poisoning of grazing animals.

The introduced perennial grasses used in the state are characterized by high production potential and low energy value. The principle constraints associated with their production include establishment difficulties, high nitrogen fertilizer requirement, and intensity of management necessary to optimize yield of digestible nutrients on a consistent basis. The perennial warm and cool season grass species are further characterized by great genetic variability and consequently very significant genetic improvement potential. Much additional progress is needed in quantifying the effects of management variables on perennial pasture species and in the development of systems models to guide decisions for maximizing of their net economic returns.

Although introduced grasses are harvested mainly by grazing animals, sizable amounts are processed as hay and sold on the open market. On a per unit basis many of these forage crops because of their high production potential can compete with grain crops in the production of protein. Energy efficient processing methods must be developed however, before this potential can be fully realized.

Nitrogen fertilizer will continue to rise in cost in the future because of its natural gas base. Although nitrogen fertilizer is the most dependable means of increasing forage quantity and quality, its use on pastures in Oklahoma would depend on the prices paid to producers for meat and milk. The best alternative for improved production is more wide spread use of grass-legume mixtures for grazing. Winter hardiness, growth during the winter, and drought tolerance are not always satisfactory for legumes introduced into the state, although some legumes developed in the southeast produce quite well in Oklahoma. Legume use will spread to central and western

Oklahoma as productive adapted legumes are developed. The grazing management essential to maintain perennial legumes in a sward or to optimize production must be developed for Oklahoma producers to remain competitive.

Alfalfa. Alfalfa production is an essential part of the beef, horse, and dairy industries of the southern plains and its importance will continue to increase with higher costs of energy. It is valued for both the fact that it produces a high quality forage without annual seeding costs and because it increases nitrogen levels in the soils, which is valuable if rotated with other crops. Probably the two greatest problems with alfalfa production at present are related to harvest management and to pest control. Losses due to pests represent the greatest limitations to increased alfalfa production at the present time in Oklahoma. A variety of insects, pathogens, and weeds cause reduced production in alfalfa. The most important forage insect pests include the spotted alfalfa aphid, the blue alfalfa aphid, alfalfa weevil, and the pea aphid. In addition seed production insect pests such as lygus bugs and the alfalfa seed chalcid are important. Many weeds are found in our alfalfa fields but henbit, winter annual grasses, and pigweed are often among the more dominant species. Alfalfa stands are not as long lived as we would like to see in Oklahoma and we suspect that phytophthora rootrot is a significant cause.

Alfalfa hay is an important part of the income of many southern Oklahoma alfalfa producers. Four to five cuttings per summer is the normal procedure in Oklahoma with average yields of 3.3 tons per acre. Producers generally are able to produce more alfalfa than they can easily sell at a good price. If marketing problems can be resolved they will probably be receptive to new production practices and varieties. Marketing this hay through the new "Haymarket" program will be of significant help to our growers.

Alfalfa seed production at one time was important to the state. This industry shifted to western states using improved production practices. The apparent constraints to seed production are primarily the lack of sufficient numbers of insect pollinators and the knowledge of their management along with problems caused by insects that feed on alfalfa seeds before harvesting. Research is being conducted to try to solve these problems.

Presently pest controls emphasize solutions for individual problems as they occur. These controls are often quite expensive with little consideration for the most efficient use of the resources available. For example, use of resistant varieties in alfalfa production would save producers millions of dollars annually. Possible interactions between control measures and the various pest complexes are usually not considered and the adverse effects of pest regulation practices on non-target organisms are often ignored. One of the most effective means

for controlling many of these pests would be the use of resistant varieties, for which we have an alfalfa breeding program.

Recent research in Oklahoma suggests that harvest management may be different from that in some of the eastern and northern alfalfa growing areas. We are finding that the first harvest can be made well before the first signs of bloom when only a few small flower buds are observed. Harvesting at this early stage of growth can help to control weeds by reducing their seed set, can help control insects by removing the forage and exposing them to sunlight, and produces a high quality feed without reducing stand longevity or yield. Similar research has recently shown that harvesting established stands of alfalfa at any fall date has little or no effect on spring forage yields and stand persistence. Alfalfa in Oklahoma may never go completely dormant and consequently green leafy material remaining after the last fall harvest is present for photosynthesis and may provide for the plants winter and early spring energy needs.

There are many problems associated with the production of forages in Oklahoma. There are also many opportunities in both our research and our extension activities related to forages. In spite of these problems we are optimistic about the potential for Oklahoma to provide its share of the expected increase and demand for range and tame forages in the United States.

FORAGE BREEDING PROGRAMS AT THE OKLAHOMA STATE UNIVERSITY

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Presently there are two forage breeding projects at the Oklahoma State University dealing, respectively, with grasses and alfalfa. The purpose of this report is to provide an overview of the work that is in progress in each of these two projects.

The broad objectives of the grass breeding project are to: 1) develop new cultivars that are superior to existing ones in such characteristics as adaptation, yield, and forage quality, 2) evaluate new accessions and selections of forage plants to determine their adaptation and potential value in Oklahoma agriculture and 3) investigate the reproductive mechanism, breeding behavior and improvement potential of important and potentially important forage species. Breeding and/or selection work is presently underway with four grass species: bermuda (*Cynodon* spp.), introduced (Old World) bluestems (*Bothriochloa* spp.) eastern gamagrass (*Tripsacum dactyloides*), and kleingrass (*Panicum coloratum*). A brief description of the principle areas of endeavor in each of these species follows.

The bermudagrass breeding program has been underway for several years and has been primarily concerned with the improvement of nutritive value in vegetatively propagated varieties. This work encompasses the interspecific hybridization of high quality but nonwinterhardy plants belonging primarily to *Cynodon nlemfuensis* varieties *nlemfuensis* or *robustus* with well-adapted but relatively low quality plants belonging primarily to the taxon *Cynodon dactylon* var. *dactylon*. The initial interspecific crosses were made in the 1960's and over the years a modified recurrent selection program has been used in an attempt to increase the frequency of genes enhancing forage quality and other physiological and morphological characteristics related to yield and adaptation. Progress is being made in combining the desirable attributes of the

parental species. We presently have in our breeding nurseries progeny selections that are relatively winterhardy and significantly higher in dry matter digestibility than check cultivars such as Midland. Although most of the selections of this type are deficient in one or more performance characteristics (forage yield, disease resistance, or establishment characteristics), they serve as parents of progeny populations in which further selection is practiced.

Another objective of the bermudagrass breeding program is the development of seed-propagated cultivars for forage and turf use. In the early stages of the bermudagrass program, some accessions from the germplasm collection were found to have relatively good seed set and apparent high seed production capability. Subsequent testing showed that excellent seed yields could be produced from fields planted to a mixture of two such self-incompatible, cross-compatible clonal plants. In a 3-year study (1974-1976) conducted at the Southwestern Livestock and Forage Research Station near El Reno, Oklahoma, an average seed yield of 743 kgs/ha was produced. The parental plants possessing relatively good fertility and their progeny populations are winterhardy but do not possess the fineness of texture desired in a turf cultivar nor the yield potential desired in a forage cultivar. Hence, we initiated a restricted recurrent phenotypic selection program for fertility and plant type. In this program the first level of selection is made for plant type, i.e., forage versus turf, and then within each of these categories, selection is practiced for fertility as expressed by percent of open-pollinated seed set. The second cycle of selection is presently underway in this program.

The introduced bluestems possess a number of desirable attributes which, in our opinion, will insure their continued use as pasture grasses in the southern Great Plains. They are easily established, aggressive, persistent, productive, and have the ability to tolerate such stresses as drought and overgrazing but still retain a stand. The Plains bluestem variety was released in 1972 by the Oklahoma Agricultural Experiment Station and has been enthusiastically accepted in a large geographical area on the southern Great Plains. The obligate and facultative modes of apomictive reproduction found within the genus make hybridization difficult, but some crossing can be done between facultative parents and between obligate and facultative parents where the obligate apomictic parent is used as the male. Some hybridizations have been made between Bothriochloa ischaemum and Bothriochloa intermedia in an attempt to combine the superior winterhardiness of the former with the greater vigor of the latter species. The majority of the improvement effort, however, has been directed toward the selection of existing superior biotypes within the germplasm collection.

Eastern gamagrass is native to much of the eastern half of the United States and is generally regarded as a "high quality" grass because of its superior palatability. Its exceptionally good palatability to all classes of livestock is attested to by the fact that it has been eliminated from much of its native habitat by overgrazing and presently is found only in areas protected from continuous grazing. Our basic objective with eastern gamagrass is to elucidate its potential for use as a grazed or stored forage and to determine the extent of genetic variation for traits of agronomic importance and the breeding behavior of the species. Present indications are that there is a wide array of genetic variation for most of the important agronomic traits such as yield and quality of forage, and seed production and its components. However, the most important and yet unanswered question relates to the basic nutritive value of the species. The expense and difficulty of establishment and the necessity for a high level of management that will be necessary for sustained high yield of gamagrass detract from its potential and dictate that it must be outstanding in some other characteristics. That characteristic most logically should be nutritive value. A cooperative experiment with dairy scientists was recently completed in which lactating dairy cows were fed gamagrass and alfalfa hays. The gamagrass hay was comprised of initial spring growth cut at the boot stage and 5-week old regrowth. The alfalfa hay was also comprised of the first and second cuttings with each cutting being made at approximately 10% bloom. Cows fed the gamagrass hay had significantly less dry matter intake per day (19.20 versus 20.07 kgs/day) than did the cows consuming the alfalfa hay. Cows consuming gamagrass hay also produced significantly less milk than did the cows on alfalfa (22.93 versus 24.06 kgs/day). These results suggest gamagrass may not be too different in forage quality from other grasses, particularly the sudan grasses and sorghum-sudan hybrids. However, data are needed comparing the performance of grazing animals on gamagrass and other suitable grass controls in order to more firmly establish its basic nutritive value.

Kleingrass is a warm-season, perennial, bunch grass indigenous to Africa. It possesses drought tolerance, is a prolific seed producer, is easily established, is a little higher in forage quality than bermudagrass cultivars such as Coastal and Midland, and is valuable as a wildlife habitat for quail and other wild game birds which thrive on its seeds. Kleingrass is presently used most extensively in western Texas north to about 34th parallel. Its marginal winterhardiness does not allow it to be used reliably north of this line and consequently it cannot be used anywhere in Oklahoma presently. Our sole objective with kleingrass is to develop a more winterhardy cultivar that can be used in the southern half of Oklahoma. A restricted recurrent phenotypic selection program is underway which encompasses the selection and intercrossing of the most

winterhardy field grown plants. Two cycles of selection have been completed to date.

The basic objective of the alfalfa breeding program is the incorporation of multiple pest resistance into cultivars that are well-adapted to Oklahoma. Oklahoma lies in a transition zone in terms of the amount of winterhardiness needed in alfalfa cultivars. Cultivars developed for states north of Oklahoma tend to go dormant earlier in the fall than most producers would like, while those cultivars developed for southern and southwestern states, with less severe climatic conditions than Oklahoma's, do not have enough winterhardiness to persist under Oklahoma conditions. We are testing germplasm pools possessing a wide array of dormancy to identify the least dormancy required for persistence.

Oklahoma has most of the major alfalfa insect and disease pests found in other alfalfa producing states. These include the alfalfa weevil, the spotted, pea, and blue alfalfa aphids, potato leafhoppers and various foliage feeding caterpillars. A sizable amount of alfalfa seed is also produced in the state, and the alfalfa seed chalcid and the lygus bug are major insect pests of that enterprise. Important alfalfa diseases found within the state include anthracnose, downy mildew, lepto leafspot, spring and summer blackstem, and *Phytophthora*, *Fusarium* and *Phymatotrichum* root rots. Damage from these pests in reduced forage yield varies from season to season, but all will normally be important sometime during the life of a stand. Emphasis is on the development of germplasm pools containing high levels of genetic resistance to as many of these insect and disease pests as is possible. Presently the bulk of the effort is being spent on the incorporation and/or increase in the level of resistance to spotted and blue aphids and to anthracnose and *Phytophthora* root rot. Conventional greenhouse procedures are used to screen for resistance to aphids and anthracnose. In these procedures seedling plants grown in flats of sterilized soil are infested with the pest organism and the surviving plants are polycrossed to produce a progeny population in which subsequent screening and recurrent selection can be practiced. *Phytophthora* root rot screening is presently done primarily under field conditions using irrigation to maintain saturated soil conditions necessary for disease development. Most of the germplasm pools used in the program have satisfactory levels of resistance to the pea aphid and bacterial wilt. All practical efforts are made to maintain resistance to these pests. Efforts are also made in some of the breeding populations to retain, or to incorporate, resistance to the alfalfa weevil while increasing resistance to the other pests.

The goal of this work is, as indicated, to develop germplasm pools which contain high levels of resistance to multiple insect and disease pests and from which cultivars well-adapted

to Oklahoma and surrounding areas can be extracted. This project was initiated in 1977. Progress to date has been the development of broad gene base germplasm pools tracing to six different source populations: Dormants (from northern Great Plains), semi-dormants (from southern plains and upper south), moderately dormant types (Beltsville-6), Oklahoma Commons (general adaptation), and Starnes Farm material (for resistance to weevil and anthracnose). To each of these pools we have increased the frequency of genes for pest resistance through one or two cycles of selection for one to four pests.

RANGE RESEARCH AT THE SOUTHERN PLAINS RANGE RESEARCH STATION

P. L. Sims

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The Southern Plains Range Research Station (SPRRS) is located at Woodward, Oklahoma, in the northern part of the Southern Plains. This research center has direct responsibility for range and range livestock research in the High Plains, Rolling Plains and Breaks, Sandstone and Flint Hills, and the Reddish Prairie resource areas. The long-term average annual precipitation at the research station is 58 cm, with a range of 25 to 107 cm over 100 years. Approximately 70% of this precipitation occurs during the summer months. Summer temperatures average 20 C compared to 7 C in the winter, with a range from -32 to 45 C.

MISSION

The mission of the SPRRS is to increase the efficiency of red meat production and range resource utilization through integrated management of energy flow, nutrient cycling, and hydrologic dynamics in forage-animal production systems in a manner consistent with perpetuation of the range resource. This mission is based on the "ARS National Research Program [for] Improved Vegetation and Management Practices for Range" (1976), which addresses three broad technological objectives: 1) germplasm enhancement, 2) development of range improvement practices, and 3) the development of grazing management systems. The station mission also supports the "Agricultural Research Service Program Plan" (1983a, 1983b).

PROGRAM INTEGRATION

Five research program areas established for the station include 1) forage germplasm enhancement, 2) forage plant physiological ecology, 3) rangeland soil-plant relationships, 4) range management and plant-animal interaction, and 5) rangeland systems analysis. Each of these areas is supported by a series of objectives for research, and approaches vary from process-oriented studies to integrated interdisciplinary studies. The research is conducted by a team of scientists composed of an agronomist,

plant physiologist, soil scientist, range scientist, and systems ecologist. The following is a brief synopsis of some aspects of each of the station's research programs.

Germplasm Evaluation and Enhancement

Old World bluestems. Extensive research with Old World bluestems (*Bothriochloa* spp.) has shown that they have significant potential for use not only in the Southern Plains but throughout many regions of the United States. These grasses can contribute significantly to beef production and soil conservation. Presently, the primary use of Old World bluestems is to reclaim marginal croplands interspersed among the region's rangeland.

Research at the SPRRS helped to elucidate the agronomic, physiological, ecological, and animal utilization characteristics of the Old World bluestems. For example, basic studies have shown measurable differences in carbon dioxide exchange rate, water-use efficiency, and turgor maintenance between various accessions of Old World bluestems. These characteristics may be related to performance during drought and perhaps to other stress conditions (Coyne et al. 1982). Such results indicate that the Old World bluestems comprise a broad germplasm reservior that can be tapped for specific uses in forage-based beef production systems in the Southern Plains and throughout the southeast United States.

These grasses have produced as much as 200 pounds of beef to the acre under semiarid to subhumid conditions (Sims and Dewald 1982), approximately four times what can be expected from well-managed native range. 'Plains' bluestem has been interseeded into an overgrazed mixed-grass prairie site. During subsequent years total forage production on the site was significantly increased in comparison to the check plots with no 'Plains' bluestem (Berg and Sims, in press).

Many grasses such as the Old World bluestems have "chaffy seed," which is difficult to harvest and process. A seed harvester has been developed that combines both the flailing and vacuum principles into one unit for stripping seeds of this kind (Dewald and Beisel 1982). Work is underway to develop technology to process the chaffy seed to bare caryopses and thus facilitate planting.

Eastern gamagrass. Eastern gamagrass (*Tripsacum dactyloides*) is a highly productive, extremely palatable grass that has received sporadic attention from researchers over the last 100 years. This grass has produced 3 to 4 metric tons of dry matter per hectare under irrigation at the SPRRS. This grass under optimum conditions has rapid regrowth potential and provides significant forage production on relatively fertile lands. A study of seasonal vegetative establishment and shoot reserves of eastern

gamagrass (Dewald and Sims 1981) showed that planting of shoot bases during the dormant period resulted in excellent stands. Some recently acquired accessions of eastern gamagrass germplasm have markedly greater seed production potential than previously acquired accessions. There appears to be sufficient genetic diversity in this species to support further germplasm development (Taliaferro et al. 1982).

Weeping lovegrass. Weeping lovegrass (*Eragrostis curvula*) has been studied for more than 30 years. This research has led to wide usage of this species on sandy lands throughout the Southern Plains (Shoop et al. 1976, Voigt et al. 1970). Weeping lovegrass is a highly productive, drought-tolerant, warm-season species which can be used alone or in complement with native rangeland or other forages to optimize beef production on some fragile lands that are subject to wind erosion.

Other species. Work has been conducted on an array of native species for over 40 years; species studied include sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), sand bluestem (*Andropogon gerardi* var. *hallii*), and an assortment of cool-season species (McIlvain and Savage 1954). Currently, a collection of *Andropogon gerardi* accessions from a number of habitats is being gathered and grown in a common garden for detailed physiological and ecological studies that should lead to a greater understanding of the physiology and the ecology of this plant species and, ultimately, to an improved germplasm of this major component of native ranges in the Great Plains.

Plant-Animal Interaction

A short-duration grazing system is now being evaluated with yearling stocker steers on native sandhill range. The current effort includes a 16-pasture system stocked at 120 kg of live animal per hectare compared to a normal stocking rate of 76 kg of live animal per hectare for continuously grazed control pastures. The short-duration system steers are rotated at a 3.5-day interval throughout the year with adjustment for changing rates of grass growth. Preliminary results indicate that gains for the short-duration grazing system averaged 62 kg/ha compared to about 35 kg/ha for the continuously stocked pastures. In this study, forage production, species composition, litter cover, soil water infiltration, and soil water are some of the site parameters measured.

Cow-calf research leading to improved forage-livestock management systems has been an integral part of this station's activities since 1940. A native range-complementary annual farmed forage system developed at the SPRRS has consistently resulted in weaning weights of around 320 kg from crossbred cows (Dewald and McIlvain 1975). This study has been expanded to include Brahman-Hereford F_1 females along with Angus-Hereford

cows bred to Simmental sires. These animals and their calves are being evaluated on the native range-complementary farmed forages system (4.4 and 0.4 ha, respectively) and on a native range program (7 ha per cow-calf unit). Cows on the native range system will be bred to calve in early spring while those on the native range-complementary forage system are bred for fall calving.

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BUFFELGRASS GERMPLASM RESEARCH FOR THE SOUTHERN GREAT PLAINS

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Buffelgrass (Cenchrus ciliaris L.) is a drouth resistant, perennial, warm-season species used as a range and pasture grass in arid areas with mild winter temperatures. It is apparently native to South Africa, where maximum variation exists, and extends north into India. Most natural ecotypes are obligate apomicts and obligate (completely) sexual plants have never been found in the native habitat. Fortunately the species is polymorphic, allowing for selection and use of superior introductions. Some apomictic accessions are being used for forage in arid regions of several countries and one strain, introduced into the USA about 1950, is responsible for over 90% of the revegetation in southwest Texas and north Mexico. Unfortunately, accessions received in the past have not had sufficient hardiness for consistent survival north of San Antonio, Texas and at high altitudes. Significant improvement in winter hardiness and adaptation to a wider range of soils could result in extensive use of this grass in the arid Southwest. This report reviews progress in buffelgrass improvement and the present status of germplasm research.

Chance discovery of a sexual "mutant" in a seed production field provided the first opportunity for improvement of buffelgrass. This plant proved to be heterozygous for method of reproduction and cross-compatible with apomictic ecotypes. When crossed with apomicts, both sexual and true-breeding apomictic F_1 hybrids were produced. Genetic studies showed that method of reproduction was rather simply inherited in buffelgrass and that obligate apomixis could be manipulated effectively in a breeding program (Taliaferro and Bashaw, 1966). Until recently, improvement of buffelgrass was based on hybridization of the sexual mutant with apomictic accessions and selection and evaluation of the best obligate apomictic hybrids. Crossing the sexual plant with rhizomatous

apomicts resulted in some apomictic hybrids with strong rhizomes and improved vigor, yield and earliness. Protection afforded by the rhizomes enhanced both winter survival and persistence under grazing. True tissue resistance to cold was not achieved in these hybrids but two cultivars, 'Nueces' and 'Llano' (Bashaw, 1981), derived from them are able to survive about 100 miles further north than any other buffelgrass because of their rhizomes.

As with most introduced apomictic grasses, lack of adequate native germplasm and sexual plants for use in hybridization have been serious problems in buffelgrass improvement. In 1976 we conducted an exploration in South Africa seeking new buffelgrass sources and acquired over 800 ecotypes with diverse characteristics and adaption to a wide range of soils. Some strains with exceptional drouth tolerance were recovered in a 4 to 8 inch rainfall area south of the Kalahari desert. Preliminary evaluations of the African collection for drouth and cold tolerance, vigor, seed production and digestibility were completed in 1982 and the results indicate that we have promising germplasm for the milder areas.

Facultative apomictic plants were found among the progeny of 73 of the African accessions and the remaining 733 accessions were obligate apomicts (Table 1). No obligate sexual plants were recovered from the native habitat. Embryo-sac studies showed that individual ovules of facultative apomictic plants may contain: (1) only nuceller sacs, (2) nucellar sacs and a sexual sac, or (3) a single sexual sac with no evidence of nucellar development (Johns and Bashaw, 1980). The percentage of ovules with a sexual sac was low in most facultative plants (2 to 20%), but there were plants in which more than 60% of the ovules had a sexual embryo-sac. However, the percentage of variant offspring was always much lower than the apparent sexual potential indicating that many of the sexual sacs did not function in reproduction. Some obligate sexual plants have been identified among the progeny of 22 facultative plants. A few of the sexual plants are healthy and highly fertile and represent a valuable source of new sexual germplasm. However, most were weak and low in fertility or completely sterile. Over half of the sexual plants were aneuploid (37 or 38 chromosomes) with several lagging chromosomes, and embryo-sac studies revealed high levels of female abortion.

Buffelgrass is apparently a segmental allotetraploid ($2n=4x=36$, typically 2 IV + 14 II at diakinesis) and two or three lagging chromosomes are common at anaphase I. Sterility and low vigor of the sexual plants probably resulted from structural hybridity and accumulated aberrations in the apomictic parents and from inbreeding depression. These factors along with environmental effects and grazing pressure probably account for failure to find sexual plants in the

Table 1.--Mode of reproduction and chromosome number of African buffelgrass accessions

Mode of reproduction	Chromosome number	No. of accessions
Obligate apomixis	36	102
	--	576
	40	1
	42	2
	44	3
	45	43[1]
	48	2
	54	4
Facultative apomixis	36	67
	45	6[1]
Obligate sexual	--	0

[1] Cold tolerant ecotypes with an alien genome of 9 univalents.

natural habitat. The derived sexual plants offer new prospects for hybridization and expanding the genetic base for breeding. However, considerable research is needed to identify the best derived sexual plants for use as germplasm.

Forty-nine nonrhizomatous accessions obtained in a mountainous area around Beaufort West in the lower Cape Province proved to be more winter hardy than any previous buffelgrass. These accessions, representing at least 31 different ecotypes, survived temperatures of 10 to 20° F that destroyed all but the most rhizomatous strains during the winters of 1978 and 79 at College Station and Temple, Texas. In subsequent tests at 7 locations in north Texas, 6 of the accessions have survived without winter injury for three years. Further tests are needed to determine if any of the accessions possess sufficient winter hardiness to be released as cultivars. Since dormant tissue of these plants is relatively cold tolerant compared to the other nonrhizomatous buffelgrasses, they represent a valuable source of new germplasm.

Cytological studies were conducted to determine mode of reproduction and chromosome number and behavior of the cold tolerant accessions. Six of the accessions were facultative apomicts and 43 were obligate apomicts. All 49 cold tolerant

accessions were found to be pentaploid with 36 buffelgrass chromosomes and an alien genome of 9 chromosomes that behave as univalents. The 18 buffelgrass chromsomes pair normally but the univalents show no tendency to pair among themselves or with buffelgrass chromosomes. They lag as a group of 9 at anaphase I and usually divide precociously before telophase. As a result most diads receive the whole alien genome. We assume that these plants probably were derived from fertilization of an unreduced egg in various tetraploid apomicts and that cold tolerance is conditioned by genes on the nine univalents.

We hypothesized that significant improvement in winter hardiness might be achieved if the cold tolerance of these accessions could be combined with the strong rhizomes of some of our breeding lines. Two of the most vigorous cold tolerant strains were used as male parents in crosses with sexual buffelgrass and 21 hybrids were recovered. All hybrids contained the normal buffelgrass complement (36) plus one to nine of the univalents. Twenty hybrids were sexual, and one containing all 9 univalents was an obligate apomict. Fertility in the sexual hybrids was low (5 to 20% seed set) but the apomictic hybrid set 55% seed. These results suggest that further hybridization should result in hybrids with significantly better winter hardiness. We have just initiated studies to identify the most sexual and highly fertile facultative plants among the cold tolerant strains for use as female parents in crosses with highly rhizomatous apomictic breeding lines. In addition to the usual type of hybrids we will be looking for plants derived by fertilization of an unreduced egg in the aposporous embryo sacs. This happens frequently in apomictic buffelgrass and allows for simultaneous combination of all the genomes of the female with the reduced complement of the male.

With a wealth of new germplasm including new sexual parents and two potentially useful mechanisms for winter survival we are optimistic that significant advances can be made in expanding the adaptation of buffelgrass.

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NEW SOURCES OF GENETIC VARIABILITY IN DALLISGRASS AND OTHER *PASPALUM* SPECIES

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Paspalum is a large diverse genus with more than 400 species (Chase 1929). Common dallisgrass, *P. dilatatum* Poir., one of the more economically important species in the genus, is native to eastern Argentina, Uruguay, and southern Brazil. It was introduced into the U.S. in the 1840's (Chase 1929) and has spread throughout the southeastern U.S. where it is a valuable forage grass. Dallisgrass produces good quality forage, is highly palatable, and persists under heavy grazing. Its most serious problem is low seed fertility and quality. The grass is susceptible to ergot, *Claviceps paspali* Stevens & Hall, and this undoubtedly contributes to the low seed fertility.

Common dallisgrass has 50 chromosomes that pair at metaphase I of meiosis as 20 bivalents and 10 univalents (Bashaw and Forbes 1958). This suggests it is a natural hybrid with chromosomes from three different sources. The unbalanced chromosome constitution has been preserved because common dallisgrass is an obligate apomict (Bashaw and Holt 1958). However, apomixis has prevented any improvement through conventional breeding methodology because of the lack of variability in the species (Burton 1962, Bennett et al. 1969). Plant breeders have utilized several different approaches during the past 50 years in an attempt to obtain or create variability within common dallisgrass and/or to circumvent the apomictic barrier. These include selection of plants from naturalized populations in the southeastern U.S., acquisition of plant introductions from South America, radiation to create desirable mutations, chromosome doubling, and intra- and interspecific hybridization. For different reasons, these approaches to obtain or create variability have been unsuccessful in producing improved forms of common dallisgrass. For the past several years, our primary thrust has concentrated on ways to circumvent apomixis. Some variable forms of dallisgrass have been obtained from these efforts.

PLANT INTRODUCTIONS

On three occasions since 1975, the senior author collected *Paspalum* germplasm in South America. Plant exploration was concentrated in the region where dallisgrass is considered to have originated as well as in adjoining areas. These include southern Brazil, Uruguay, northern Argentina, Paraguay, and southern Bolivia.

Six different dallisgrass biotypes have been found in the area considered to be the center of origin of the species (table 1). The common, prostrate and erect yellow-anthered biotypes have been available to plant breeders in the U.S. for many years. However, a large number of phenotypically different ecotypes of common dallisgrass representing variability not previously available have been collected since 1975. Only one or two accessions of the variable yellow-anthered biotype from a small region in the northeast part of the state of Rio Grande do Sul in Brazil were available prior to 1975. The recently acquired accessions were collected from a broader area of their native habitat and are considerably more variable than the previously available accessions. There is a wide integradation of types ranging from plants similar to vaseygrass, *P. urvillei* Steud., to the more typical yellow-anthered dallisgrass. It appears that natural hybridization is occurring between vaseygrass and yellow-anthered dallisgrass. These accessions and their progeny provide valuable sources of new germplasm and sexuality to use in the hybridization program. Two biotypes, the Torres and Uruguaiana dallisgrasses, had never been available through the U.S. Plant Introduction program. Both biotypes are considerably different from common dallisgrass (table 1) and the Uruguaiana biotype appears to have potential as a forage grass.

A forage evaluation test was conducted at Temple, Texas, from 1978-1980 to determine the forage potential of 17 different biotypes including common dallisgrass. Forage yields and IVDMD values for the accessions are presented in table 2. The erect Uruguaiana biotype produced more forage than common dallisgrass. The four common dallisgrass ecotypes which were phenotypically different than typical common dallisgrass produced less forage than common, and the Torres biotype produced the least amount of forage.

The IVDMD values for all the accessions were low because the samples were collected when the plants were mature. Common dallisgrass did not differ significantly from the other accessions in IVDMD (table 2), but there were significant differences among the Uruguaiana types in IVDMD. Because there was not a significant correlation ($r = -0.28$) between yield and IVDMD for the Uruguaiana accessions, we believe that we may be able to select a more productive plant without adversely affecting IVDMD, but more detailed studies are needed. In 1982 the seven

Table 1.--Biotypes of *Paspalum dilatatum* from South America

Name	Growth habit	Area of distribution	2n	Mode of reproduction
Common	Semi-prostrate	Northeastern Argentina, Uruguay, Southern Brazil	50	Apomict
Prostrate	Prostrate	Northeastern Argentina, Northern Uruguay, Southern Paraguay, Southern Brazil	40	Apomict
Yellow-anthered	Erect	Eastern Prov. of Buenos Aires (Argentina), Southern Uruguay	40	Sexual
Yellow-anthered	Variable	Northeastern State of Rio Grande do Sul (Brazil)	40	Sexual
Torres	Prostrate	Northeastern State of Rio Grande do Sul (Brazil)	60	Apomict
Urguaiana	Erect	Southwestern State of Rio Grande do Sul (Brazil), Northwestern Uruguay	60	Apomict

Table 2.--Performance of new dallisgrass ecotypes and biotypes [1]

Accession	Type	Forage yield	Mean IVDMD
		kg/ha	%
461	Uruguaiana	8300 a	47.8 bcd
455	"	8300 a	47.6 bcd
426	"	7600 ab	48.0 bcd
554	"	7600 ab	49.5 abc
458	"	7500 abc	47.5 cd
460	"	7400 abc	46.9 d
555	"	7300 abc	50.1 ab
427	"	6800 bcd	48.0 bcd
432	"	6500 b-e	47.3 cd
459	"	6500 b-e	48.0 bcd
544	"	6300 c-f	50.5 a
Mean	"	7300	48.3
Common	Common	6300 c-f	48.6 a-d
552	Common off type	5900 d-g	49.7 abc
543	" " "	5500 efg	49.0 a-d
547	" " "	5200 fgh	47.4 cd
351	" " "	5000 gh	48.0 bcd
Mean	" " "	5400	48.5
178	Torres	4000 h	48.4 a-d

[1]Mean of 3 years.

best accessions and common dallisgrass were planted into forage tests at Temple and Angleton, Texas, for further evaluation.

Because previous plant breeders and geneticists have used plant introductions in an attempt to improve the species, it may seem unusual that this approach is more successful today. Essentially all *Paspalum* introductions obtained prior to 1975 were collected by taxonomists from the countries where the plants were growing. Because they were unaware of the objectives of the breeding programs and did not understand the problems associated with breeding apomictic grasses, their collections did not comprise the best available germplasm. The senior author was familiar with these problems, and therefore was able, with the assistance of South American scientists, to identify valuable new ecotypes and biotypes not included in previous collections. This clearly demonstrates the necessity that the geneticist working with a particular species to explore the center of origin of the species and collect the diverse germplasm that will be of value to the improvement program.

Accessions of four other *Paspalum* species are also being evaluated at Temple. The species are *P. nicorae*, *P. plicatulum*, *P. denticulatum*, and *P. unispicatum*.

INTRA- AND INTERSPECIFIC HYBRIDIZATION

Numerous interspecific *Paspalum* hybrids have been made during the past several years. Many of these have involved the erect sexual yellow-anthered dallisgrass biotype as the female parent. Most hybrids were made for cytogenetic analysis to determine the phylogenetic relationships among various species (Burson 1983). Even though some hybrids have potential as productive forage grasses, they all lack sufficient fertility to be propagated by seed. Attempts to restore fertility in these hybrids have not been successful.

Because of sterility in the interspecific hybrids, intraspecific hybridization appears to have the most potential in producing improved germplasm. A fertile intraspecific hybrid has been produced between the yellow-anthered and common dallisgrass biotypes (Bennett et al. 1969). However, because of the instability of the 10 common dallisgrass univalent chromosomes in the F_1 hybrid, apparently some important genetic material is lost when the 10 univalents are eliminated in the subsequent generations. Recently, this yellow-anthered X common F_1 hybrid was backcrossed to common dallisgrass, and some variable purple-anthered plants have been recovered. This could provide a means of stabilizing some of the univalents as backcrossing to common dallisgrass is continued. In the future the sexual yellow-anthered plants will be crossed with the Uruguaiana biotype in an attempt to recover improved types.

TISSUE CULTURE

Variation is observed frequently in tissue culture-derived plants. When small segments (3-5 mm in length) of young common dallisgrass inflorescences or stems are placed on an agar based medium, callus tissue often develops. After the callus has increased to a sufficient size, it is transferred to other media with appropriate auxin-cytokinin content to stimulate shoot and root differentiation. These young plantlets are transplanted into peat pots in the greenhouse and eventually planted into a field nursery.

More than 300 plants have been established in a field nursery. Differences in plant size, leaf width, leafiness, and pubescence have been noted. Because we are interested in increasing drought tolerance in dallisgrass, a study was initiated to determine if there were differences in heat tolerance among the tissue culture-derived plants. Using a heat tolerance test (Sullivan 1972), 250 plants were tested under both drought stressed and non-stressed conditions. When drought stressed, the percent cellular damage from a heat challenge of 50°C for 45 min ranged from 20 to 70% with the largest number of plants occurring in the 50% damage category. The common dallisgrass control was also in the 50% damage category. Plants were visually rated for their susceptibility or resistance to stress when under drought conditions. The visual ratings and the cellular damages from the heat tolerance test were negatively correlated ($r = -0.32^{**}$). When the plants were sampled under non-stressed conditions, the percent damage ranged from 60 to 100% with the most frequent category being 80%. Common dallisgrass was in the 80% category. These findings suggest that differences occur among the tissue culture-derived plants in their ability to acclimate to heat or drought stress. Because common dallisgrass is an obligate apomict, this amount of variability would not normally be expected and, in fact, was not observed among the common dallisgrass checks. Therefore, it appears that real differences do occur in the tissue culture-derived plants. Research is underway to further evaluate the physiological and genetic bases for these differences under controlled conditions. Variants produced in this manner may be important in extending the range of adaptation of common dallisgrass into drier regions.

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CLOVER AND SPECIAL PURPOSE LEGUME GERMPLASM RESOURCES FOR THE FUTURE

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INTRODUCTION

Between 1950 and 1970, research on clovers and special purpose legumes was greatly reduced in the U.S.; however, in the last ten years, interest has rekindled in the utilization of legumes in pastures and in conservation tillage systems. The energy crisis stimulated part of this interest as well as a need perceived by livestock producers for higher quality forage with better seasonal distribution. Recent economic conditions in the livestock industry have resulted in erodable land being placed in row crops. Increased erosion clearly shows the need for better conservation tillage systems. Legumes should be an integral part of these systems.

Presently, there are 75 legume species (excluding alfalfa) in public improvement programs in the Southeastern U.S. This paper will summarize the state and the U.S. Department of Agriculture programs involved in improvement of these 75 legume species. Also, examples of current research that will result in improved legume germplasm for the future will be cited.

AREAS FOR IMPROVEMENT

There are a number of areas where significant improvement can be made in the germplasm of the future:

1) Increased forage yield distribution and quality.
2) Resistance to fungal pathogens.
3) Resistance to legume viruses.
4) Nematode resistance.
5) Insect resistance to primary pests as well as to vectors of viruses.
6) Improved N_2 fixation by developing a more efficient symbiotic relationship with improved *Rhizobium* strains.

7) Increased drought tolerance and winterhardiness to improve persistence and increase adaptation of legumes to Southeastern U.S. climatic conditions.
8) Improved seed production to enable producers to establish initial stands and improved reseeding in annuals for establishment of subsequent stands.
9) Development of interspecific hybrids to utilize traits from other legume species.
10) Plant introduction and evaluation to broaden the gene base and reduce genetic vulnerability.

WHITE CLOVER

White clover, Trifolium repens L., is a perennial clover widely adapted for use in pastures of the Southeastern U.S. Alabama, Florida, Louisiana, Mississippi, North Carolina, and South Carolina are presently involved in white clover improvement (table 1). The standard white clover cultivars are the ladino types, 'Regal' and 'Tillman', and the intermediate types 'Louisiana S-1' and 'Nolin's Improved'. Regal is a five-clone synthetic released by the Auburn University Agricultural Experiment Station in 1962 (Johnson et al. 1970) while Tillman, a six-clone synthetic, was released by the South Carolina Agricultural Experiment Station and the U.S. Department of Agriculture in 1965 (Gibson, Beinhart, and Halpin 1969). Louisiana S-1, a five-clone synthetic released by the Louisiana Agricultural Experiment Station in 1952 (Hollowell 1958), and Nolin's Improved, a naturalized cultivar, behave as reseeding annuals in the Southeast.

Objectives of white clover research include improvement of persistence and development of resistance to viruses, root diseases, and nematodes. Prior to retirement, Dr. P. B. Gibson led an extensive and productive multidisciplinary program on white clover at Clemson, S.C. He led a research team that produced 11 interspecific hybrid combinations, eight for the first time, among five species of clover (Chou and Gibson 1968; Gibson and Beinhart 1969; Gibson et al. 1971; Gibson and Chen 1975). The Clemson team developed a technique to screen white clover plants for resistance to root-knot nematodes (Baxter and Gibson 1959) and released SC-1 root-knot nematode resistant germplasm in 1972 (Gibson 1973). A forthcoming virus-resistant germplasm release was developed through a five-state cooperative project coordinated by Dr. P. B. Gibson. Plants were screened by mechanical inoculation, aphid inoculation, and field tests for resistance to alfalfa mosaic virus, peanut stunt virus, and clover yellow vein virus. Further field screening resulted in 44 clones being found resistant to these viruses in all tests. A germplasm release of this material will be made shortly. Other promising white clover germplasm includes Florida XP-1 and XP-2 developed by the Florida Agricultural Experiment Station and the Brown Loam germplasm developed by the Mississippi Agricultural Experiment Station and the U.S. Department of Agriculture.

Table 1.--Forage legumes other than alfalfa in public improvement programs in the Southeastern United States[1]

Legume	State								
	AL	FL	GA	KY	LA	MS	NC	SC	TX
Clovers (*Trifolium* spp.):									
Arrowleaf (*T. vesiculosum*)		B	B*		S	B,R1			B
Ball (*T. nigrescens*)	B,R2				S				
Berseem (*T. alexandrinum*)		S			S	S,R2*			S
Crimson (*T. incarnatum*)		B		S,R2	S	B,R1,R2*			B
Kura (*T. ambiguum*)		S		B,R2	S	S*			S
Mike (*T. michelianum*)				S,R2		S,R2*			
Mutabile (*T. mutabile*)	B,R2								
Persian (*T. resupinatum*)		S			S	S*			
Purpureum (*T. purpureum*)	B,R2								
Red (*T. pratense*)		B,R2		B,R1,R2	S				
Rose (*T. hirtum*)					S				S
Semipilosum (*T. semipilosum*)					S				
Strawberry (*T. fragiferum*)					S				
Subterranean (*T. subterraneum*)		S	B*		S	B,R2*			B
White (*T. repens*)	B	B,R1			B	B,R2*	B*	B	
Zigzag (*T. medium*)				S,R1					
Lespedeza:									
Annual:									
L. striata					S		R1*		
L. stipulacea					S		R1*		
Sericea (*L. cureata*)	B,R1			S,R1	S		R1*		
Lupine (*Lupinus* spp.):									
Bicolor (*L. hispanicus*			B,R1*		S				
Blue (*L. angustifolius*)			B,R1*		S				
White (*L. albus*)			B,R1*		S				

Table 1.--Forage legumes other than alfalfa in public improvement programs in the Southeastern United States--continued

Legume	State								
	AL	FL	GA	KY	LA	MS	NC	SC	TX
Vetch (Vicia spp.):									
Bigflower (V. grandiflora)				S,R1	S				
Common (V. sativa)	B,R1				S				
Hairy (V. villosa)	B,R1				S				
Other legumes:									
Aeschynomene americana		B,R2			S				
A. falcata					S				
A. rudis					S				
A. sensitiva					S				
Alyce clover (Alysicarpus vaginalis		B,R2			S				
Canavalha brasilianis					S				
Cassia fasiculata					S				
Centrosema arenarium					S				
C. pascuorum					S				
C. virginianum		S			S				
Crownvetch (Coronilla varia)							S		
Desmodium heterocarpon		S,R1			S				
D. canum			B,R1*		S				
D. barbatum		S			S				
D. intortum					S				
D. sandwicense					S				
D. uncinatum					S				

Table 1.--Forage legumes other than alfalfa in public improvement programs in the Southeastern United States--continued

Legume	State								
	AL	FL	GA	KY	LA	MS	NC	SC	TX
Galactia striata					S				
Hairy indigo (Indigofera hirsuta)		S			S				
Hedysarum coronarium					S				
Hyacinth bean, Lablab purpureus (=Dolichos lablab)			B,R1*		S				S
Illinois bundleflower (Desmanthus illnoensis)									B,R1
Leucaena leucocephala		S			S				S
Lotonis bainesii					S				
Macrotyloma auxillare					S				
M. uniflorous					S				
Mimosa strigillosa					S				
Mung bean (Phaseolus aureus)					S				
Perennial peanut (Archis glabrata)		S,R1							
Perennial soybean (Neonotonia wightii)					S				
Pigeon pea (Cajanus cajan)		B							
Psophocarpus palustris					S				
P. scandens					S				
P tetragonolobus					S				
Rhynchosia minima					S				
Sesbania spp.					S				

Table 1.--Forage legumes other than alfalfa in public improvement programs in the Southeastern United States--continued

Legume	State								
	AL	FL	GA	KY	LA	MS	NC	SC	TX
Siratro:									
Macroptilium atropurpureum		S			S				
M. lathyroides					S				
Stylosanthes humilis		B			S				
S. hamata		S			S				S
S. guianensis		S			S				S
S. scabra									S
S. subsericea					S				
S. tuberculata		S							
Trefoil (_Lotus corniculatus_)	B,R1		S,R1	S,R1	S				
Vigna carocalla		S							
V. luteola		S			S				
V. unguiculata					S				
Winterpea (_Pisum sativa arvense_)						R1			
Zornia spp.		S			S				

1/ Results of a survey completed in 1977; updated May 1983.

* = USDA.

B = Breeding program in progress.

S = Evaluation and selection.

R1 = Released germplasm or cultivar.

R2 = Release probable within 5 years.

RED CLOVER

Red clover, *Trifolium pratense* L., is a perennial clover which is more widely used in other areas of the U.S. other than the Southeast. Florida, Kentucky, and Louisiana are involved in improvement programs on red clover (table 1). For the Southeast, the standard cultivars are 'Kenland' and 'Kenstar'. These two cultivars were developed by the Kentucky Agricultural Experiment Station and the U.S. Department of Agriculture in 1951 (Hollowell 1951) and 1973 (Taylor and Anderson 1973), respectively.

Objectives of red clover improvement programs include increasing persistence in the Southeast, developing fundamental cytogenetic knowledge on *Trifolium* species, and increasing resistance to viruses, root diseases, and nematodes. Dr. N. L. Taylor and associates at the Kentucky station have established an extensive red clover improvement program. Recent red clover germplasm releases include 11 gene markers (Taylor 1982) and 9 generations of bulked plant introductions (Taylor 1979). The Kentucky program has also been instrumental in interspecific hybridization of *Trifolium* species and has released germplasm of *Trifolium sarosiense* x *T. alpestre* and *Trifolium medium* x *T. sarosiense* in 1978 (Taylor and Quesenberry 1978a, 1978b).

ARROWLEAF CLOVER

Arrowleaf clover, *Trifolium vesiculosum* Savi., is a winter annual clover that has received a great deal of interest in the Southeast recently. Florida, Georgia, Louisiana, Mississippi, and Texas are involved in arrowleaf clover improvement (table 1). The standard cultivars of arrowleaf clover are 'Amclo', 'Yuchi', and 'Meechee'. Amclo, an early-maturing cultivar, was released by the Georgia Agricultural Experiment Station and the U.S. Department of Agriculture (Beaty et al. 1965). Yuchi, a later-maturing type, was released by the Auburn University Agricultural Experiment Station (Hoveland 1967). Meechee, the latest maturing cultivar with the most winterhardiness, was released by the Mississippi State University Agricultural Experiment Station and the U.S. Department of Agriculture (Knight et al. 1969).

The objectives of arrowleaf clover research are to obtain early emergence with uniform stands, increase late spring persistence, improve drought tolerance, and increase resistance to viruses, root diseases, and nematodes. Virus diseases are a major problem not only in arrowleaf but in many of the other true clovers. Viruses can reduce the clover stand by direct effect or by increased susceptibility to secondary pathogens through reduced plant vigor. Arrowleaf clover is more susceptible to nematode damage than other annual clovers (Nichols et al. 1981). Nematode-resistant germplasm should be forthcoming from the Florida breeding program.

CRIMSON CLOVER

Crimson clover, Trifolium incarnatum L., is a winter annual legume with a distinctive bright crimson flower. Florida, Kentucky, Louisiana, Mississippi, and Texas have active improvement programs in crimson clover (table 1). The standard cultivars are 'Dixie', 'Chief', 'Autauga', and 'Tibbee'. Dixie was released in 1946 by the Georgia Agricultural Experiment Station and the U.S. Department of Agriculture (Hollowell 1953). Chief and Tibbee were released by the Mississippi Agricultural Experiment Station and the U.S. Department of Agriculture (Hollowell 1960 and Knight 1972).

The objectives of crimson clover research are to improve N_2 fixation, improve fall growth, reduce seed shatter and lodging, and increase resistance to the clover head weevil, viruses, root diseases, and nematodes. The clover head weevil is a major insect problem on crimson clover. Feeding by this insect reduces the reseeding ability of crimson clover and may result in poor stands in subsequent years. A screening program is presently underway in Mississippi to develop resistant germplasm.

SUBTERRANEAN CLOVER

Subterranean clover, Trifolium subterraneum L., is a winter annual clover which only recently has been extensively grown in the Southeast. Florida, Georgia, Louisiana, Mississippi, and Texas are involved in the improvement of subclover (table 1). The standard subclover cultivars are 'Mt. Barker', 'Nangeela', 'Woogenellup', and 'Meteora', which are imported from Australia. Objectives of subclover programs include evaluation of Australian material for adaptation to the Southeastern U.S., increasing forage yield, improving reseeding ability, and developing resistance to viruses and mildew. A subclover germplasm with increased adaptation to the Southeast has been developed by the Mississippi Agricultural Experiment Station and the U.S. Department of Agriculture. The Mississippi ecotype subclover has persisted for over 30 years from an original seeding of the Australian cultivars Mt. Barker, 'Bacchus Marsh', and 'Tallarook'. This subclover will be released as germplasm or as a cultivar in the near future.

BERSEEM CLOVER

Berseem clover, Trifolium alexandrinum L., is a winter annual clover that is in the improvement programs of Florida, Louisiana, Mississippi, and Texas (table 1). Presently, there are no standard cultivars for the Southeast except Florida since no cultivars have adequate winterhardiness. The main objective of berseem clover improvement is to increase the winterhardiness of the species. Secondary objectives include developing resistance to leaf diseases and improving recovery after clipping. A winterhardy berseem clover has been developed in

Mississippi from plants of the Italian cultivar 'Sacromonte' that survived field temperatures as low as 5° and 8° F. A release of this material will be made shortly.

PERSIAN CLOVER

Persian clover, Trifolium resupinatum L., is widely adapted in the South. Producers' fear of bloat has caused this species to fail to reach its potential as a forage crop. A wide range of plant material, representing wide variations in maturity, forage yield, and recovery after clipping, is available through plant introduction (Massey 1966). Weihing (1962) applied selection pressure for hard seed to desirable agronomic types from three plant introductions to develop the improved, hard-seeded cultivar 'Abon'. Reluctance to use Persian clover should diminish with present knowledge and use of poloxalene in blocks and in molasses mixtures.

Interest in Persian clover has increased, and Abon is being evaluated in regional tests.

BALL CLOVER

Interest in ball clover, Trifolium nigrescens L., has increased in Alabama, Mississippi, and Louisiana. The Alabama Experiment Station includes this species in its improvement program. Breeding objectives in this program are 1) increased forage and seed yield, and 2) improved pest resistance. Recently a farmer variety, 'Segrest' was added to the regional variety tests, and the Alabama station plans to make a germplasm release in the near future.

VETCH

Vetches are used most commonly as winter cover crops in the Southeast, with 75% of the total acreage in Oklahoma, Arkansas, Texas, and Louisiana. However, vetch makes hay, silage, and pasture of high quality. Hairy vetch, Vicia villosa Roth, accounts for 85% of the vetch acreage in the U.S. In 1959, the Alabama Agricultural Experiment Station released 'Warrior', a variety of common vetch, Vicia sativa L. (Donnelly 1965a). Warrior vetch is resistant to the vetch bruchid and three species of root-knot nematode and produces high forage and seed yields.

The Louisiana Seed Company is distributing seed of four proprietary varieties from the Alabama program (Donnelly 1979). These recent releases are 'Vantage', 'Cahaba White', 'Nova II', and 'Vanguard'.

At the Kentucky Agricultural Experiment Station, a locally adapted strain of bigflower vetch, Vicia grandiflora var. kitaibeliana W. Koch, has shown promise as a pioneer legume in

pasture renovation research conducted by Templeton and Taylor (1975). 'Woodford' has been released as a new variety of bigflower vetch from this work.

LESPEDEZA

Both perennial and annual lespedezas have been under evaluation for use in the Southeast. Most of the current research is on the perennial sericea lespedeza, Lespedeza cuneata (Dum.) G. Don, rather than the two annual lespedezas--striate, L. striata (Thunb.) Hook & Arn., and Korean, L. stipulacea Maxim. Alabama, Kentucky, Louisiana, and North Carolina are involved in sericea lespedeza improvement (table 1). The main objectives of sericea lespedeza research have been to develop a lespedeza low in tannin and to increase nematode resistance. Until recently, the standard cultivars of sericea lespedeza were 'Arlington', 'Serala', and 'Interstate'. Serala and Interstate were released by the Auburn University Agricultural Experiment Station in 1962 and 1969 (Donnelly 1965b and 1971). In 1978, three cultivars were released. 'Serala 76' and 'Interstate 76' released by the Alabama and Georgia Agricultural Experiment Stations and the U.S. Department of Agriculture contained nematode resistance and other improvements not in the original cultivars (Donnelly and Minton 1979). 'Appalow', the first prostrate lespedeza, was released by the Kentucky Agricultural Experiment Station and the U.S. Department of Agriculture (Henry and Taylor 1981). In 1980, 'AU Lotan' was released by Dr. E. D. Donnelly of the Alabama Agricultural Experiment Station (Donnelly 1981). This cultivar is low in tannin content and has greater nematode resistance than previous sericea lespedeza cultivars.

LUPINE

Lupine species that are under evaluation in the Southeast are blue lupine (Lupinus angustifolius L.), white lupine (L. albus L.), and bicolor lupine (L. hispanicus spp. bicolor, Merino, J. S. Gladstones). The objectives of lupine improvement are to reduce the alkaloid content, increase seed shattering resistance, and increase winterhardiness. Georgia and Louisiana are involved in lupine improvement. A number of recent cultivar and germplasm releases have been made by Dr. John D. Miller, Dr. Homer D. Wells, and others of the U.S. Department of Agriculture and the Georgia Agricultural Experiment Station.

The standard cultivars of blue lupine have been 'Richey', 'Borre', 'Rancher', 'Blanco', and 'Frost'. Blanco and Rancher were released by the Georgia Agricultural Experiment Station and the U.S. Department of Agriculture in 1960 (Forbes et al. 1964 and Forbes and Wells 1967). Frost was released by the Georgia and Florida Agricultural Experiment Stations and the U.S. Department of Agriculture (Wells et al. 1980a). This cultivar showed more seed-shattering resistance than previous cultivars. Also, Georgia and the U.S. Department of Agriculture released a

winterhardy germplasm, WH-1, of blue lupine in 1980 (Wells and Miller 1981).

The standard cultivar of white lupine was 'Hope' released by the Arkansas Agricultural Experiment Station in 1970 (Offutt 1971). In 1980, the Georgia Agricultural Experiment Station and the U.S. Department of Agriculture released 'Tifwhite-78' white lupine, which has a low alkaloid content, improved winter-hardiness, and decreased seed shattering (Wells et al. 1980b). In 1982, a bicolor lupine germplasm, Bicolor-1, was released by the Georgia Agricultural Experiment Station and the U.S. Department of Agriculture (Miller and Wells 1983a).

BIRDSFOOT TREFOIL

Interest in birdsfoot trefoil, *Lotus corniculatus* L., has increased in the South. New releases are being considered in Alabama and Georgia. Kentucky recently released the cultivar 'Fergus'. These cultivars have been developed for 1) improved forage yield, 2) improved seed yield, 3) improved persistence, and 4) improved pest resistance. 'AT-P' birdsfoot trefoil will be released by the Alabama Agricultural Experiment Station if adequate seed production can be obtained.

OTHER LEGUMES

Many other legume species are involved in selection and improvement programs in the Southeastern U.S. Though not all of the species can be covered in this paper, some of the recent and forthcoming releases will be cited. The Alabama Agricultural Experiment Station is planning germplasm releases of *T. purpureum* and *T. mutabile*. The Georgia Agricultural Experiment Station and the U.S. Department of Agriculture released Tift-1 hyacinth bean (*Lablab purpureus* (L.) Sweet) germplasm in 1982 (Miller and Wells 1983b) and Tifhardy-1 *Desmodium canum* (J. F. Gmel.) Schinz and Thell. germplasm in 1981 (Miller and Wells 1981). The Florida Agricultural Experiment Station released 'Florida' *Desmodium heterocarpon* (L.) DC. in 1979 (Kretschmer et al. 1982). The Kentucky Agricultural Experiment Station released KY M-1 zigzag clover (*Trifolium medium* L.) germplasm in 1982 (Taylor et al. 1982).

In Florida, Dr. A. E. Kretschmer has an extensive evaluation program involving over 4,000 accessions of tropical legumes. Some of the tropical legumes are being evaluated at the Iberia Livestock Experiment Station in Louisiana by Dr. C. C. Shock. Although some of these species may be adapted and contribute to forage systems in the tropical part of the region, their use over much of the region will be limited by climatic conditions.

This paper covers primarily the public improvement programs for legume species other than alfalfa. However, the contribution of industry to the development, promotion, and distribution of

legume cultivars should be recognized. Private industry has been actively involved in red clover improvement with the release of many cultivars, including 'Florie' by Northrup King and Company, 'Redland II' by North American Plant Breeders, and 'Redman' by FFR Cooperative (Buker et al. 1979). 'Arcadia' is an improved ladino clover distributed by Northrup King and Company. Cal/West Seeds has a white clover improvement program with several experimentals in the regional evaluation test. The Louisiana Seed Company has increased and distributed four proprietary cultivars from the Alabama vetch breeding program (i.e., Vantage, Cahaba White, Nova II, and Vanguard) as well as Tibbee and Chief crimson clovers released by the U.S. Department of Agriculture and the Mississippi Station.

A wide range of diverse legume germplasm is available for general and for special purpose use in the Southeastern U.S. However, the large number of species involved will increase the breeder's challenge to provide the public with improved legume germplasm resources in the future.

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FORAGE ATTRIBUTES FOR IMPROVED ANIMAL PERFORMANCE

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Most forage species will provide at least moderate levels of nutrition to ruminants during brief periods of the growing season. The objective of breeding and management research is to improve those characteristics that will increase both rate of animal production and the length of time when a high rate of production can be achieved. Of the six classes of nutrients required in balanced supply by animals, carbohydrates and proteins are of major economic concern for forage diets. Minerals, vitamins, and water can be supplemented at relatively low cost. Essential lipids, like the B vitamins, appear to be provided by rumen microorganisms in sufficient quantity to all but the youngest ruminants. Attention, therefore, centers on the supply of energy-yielding compounds, primarily carbohydrates, and nitrogenous compounds, primarily protein, and the influence of plant structure on their concentration and availability.

The work of Weston and Hogan (1968) indicates that the concentration of dietary protein needed by rumen microorganisms for maximum rumen function may be as low as 6%, a value much lower than that needed by the host animal when producing at even moderate levels. In the great majority of forages, however, it is energy availability and not protein that first limits animal performance. The exceptions include stored forages having a high grain content.

Figure 1 outlines the characteristics of plant structure that bear upon digestible energy intake. Rate of fermentation in the rumen and rate of passage of undigested residues from the rumen regulate intake through their effect on chemical satiety and gut fill (Ellis, 1978; Forbes, 1980; Lippke, 1980). Extent of digestion has its obvious effect on gut fill and, therefore, on intake. The relationships between extent of digestion and rate of fermentation or rate of passage are usually positive. When plant structure is such that normal processing (i.e., grazing and chewing) results in smaller particles, rate of fermentation increases more than rate of passage and extent of

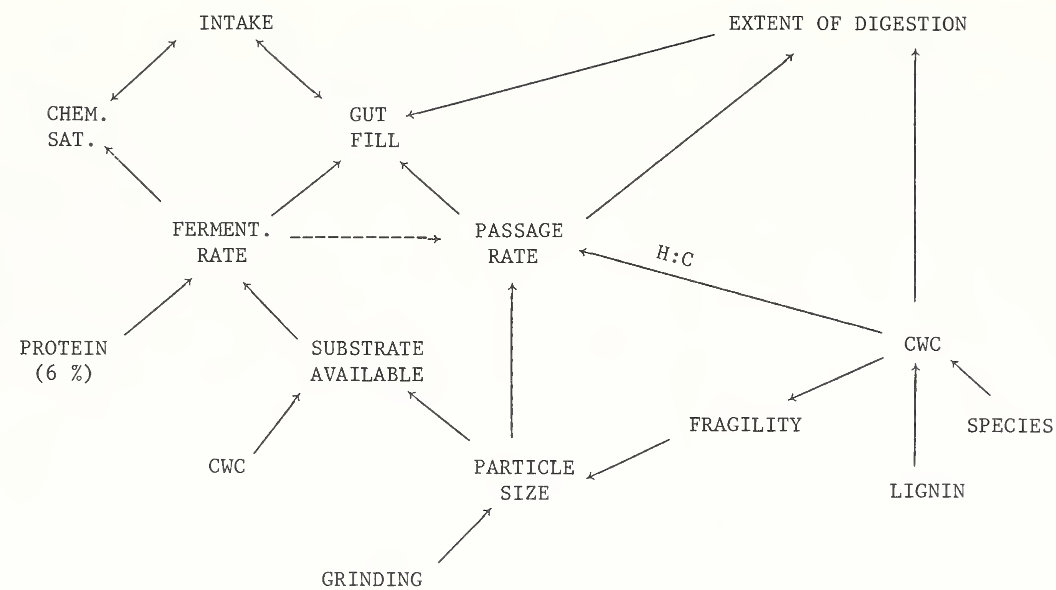

Figure 1--Factors influencing digestible energy intake from forages.

digestion increases. Mechanical grinding, on the other hand, commonly increases rate of passage more than rate of fermentation, and extent of digestion declines (Hogan and Weston, 1967).

Rate of fermentation is strongly influenced by the proportion of soluble carbohydrates in forages and the composition of structural carbohydrates, also called cell wall constituents (CWC). Fermentation of neutral detergent solubles is very rapid (Gray et al., 1967) and almost complete (Van Soest, 1967). CWC, represented analytically by neutral detergent fiber (NDF) (Van Soest and Wine, 1967), have a much slower fermentation rate that is influenced primarily by the degree of structural fragility and, hence, particle size (Laredo and Minson, 1973). Paradoxically, rate of fermentation of solubles can sometimes be too fast, as with very immature ryegrass, resulting in a disruption of rumen function, and severely reduced intake (Lippke, 1982). A minimum of about 10% indigestible fiber appears to be needed in the diet for maximum digestible energy intake (Lippke, 1982), presumably to help buffer the rapid release of acids that accompany a high fermentation rate (Van Soest, 1982).

The structural components of forages appear to be fermented at variable rates. Akin and Burdick (1975) reported that both mesophyll and phloem tissues were rapidly and totally degraded by *in vitro* rumen fermentation within 12 hr while outer bundle-sheath cells and noncutinized portions of epidermis were degraded more slowly. Sclerenchyma and lignified vascular tissue were not degraded. Akin et al. (1975) also reported that acid detergent removed approximately the same tissues from Coastal bermudagrass leaves as did *in vitro* fermentation. These observations agree with the report by Lippke (1980) indicating a high positive correlation between hemicellulose : cellulose and NDF intake, where hemicellulose = (NDF - ADF). A higher proportion of rapidly digested fiber, as indicated by a higher hemicellulose : cellulose ratio, should correlate well with increased rate of passage from the rumen and increased NDF intake.

The polyphenolic polymers, commonly referred to as lignin, within the plant cell wall appear to be responsible for the limitation of intake of most forages, both by their effect on extent of digestion and on fragility. Lignin has commonly been thought to exert its inhibitory action by preventing the physical attachment of rumen bacteria to the cell wall (Dehority and Johnson, 1961). Alternatively, Bacon (1979) has suggested that the structure of indigestible fiber is composed of a highly substituted polysaccharide chain having covalent linkages to lignin and that digestive enzymes cannot proceed past such linkages along the chain. Work is underway now to determine whether or not lignin has an inhibitory action on rumen microorganisms independent of its direct effect on utilization of plant fiber (D.E. Akin, personal communication).

The "ideal" forage for high animal performance can be summarized as having 34% neutral detergent solubles (half of that protein), 54% potentially digestible fiber having a fermentation rate of .4 hr^{-1}, and 12% indigestible fiber, which includes 3% lignin. For warm-season grasses, significant progress toward this ideal can be made by bringing NDF down to 60% and then selecting for increased mesophyll and phloem within the structural carbohydrates. Some improvements might also be made in many cool-season species by increasing NDF while reducing lignin. Researchers in forage improvement should be encouraged by the substantial gains in animal performance that can be achieved with relatively small changes in structure of most forage species.

While not included in this paper, such agronomic factors as growth habit and persistence under grazing are regarded as being at least of equal importance to those topics discussed.

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Panel Discussion: Data Required Before Releasing Forages. What Kind and How Much?

THE NEED FOR ANIMAL TRIALS

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and A. G. Matches and J. R. Forwood,
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One of the limitations in many forage breeding programs is the inability to identify, during the course of cultivar development, plant materials that would lead to improved animal productivity. Many forage breeding programs simply do not have the resources to evaluate selected materials with animals. Those forage improvement programs that have the resources for animal evaluation will often use animal evaluation as a last step prior to release. It is desirable to have animal performance data prior to release of the new cultivar.

PHASES OF EVALUATION

At the University of Missouri, we have made a commitment to evaluate new tall fescue and orchardgrass synthetics with grazing animals prior to release. The forage grass breeding procedure is directed into several phases:

Phase I. Plant introduction. Plants are obtained from various sources such as plant introduction stations, plant breeders, local collections, crosses, and cultivars.

Phase II. Identify desirable traits and genetic variability. Objectives of what trait(s) is (are) desirable in the new cultivar is (are) established. The amount and kind of genetic variability is determined to make an intelligent decision regarding the choice of the breeding procedure to incorporate the traits.

Phase III. Plant development. The breeding procedure selected is used to improve the trait(s) chosen in Phase II. The new synthetic(s) is (are) developed.

Phase IV. Small plot evaluation. During this phase we can determine what the influence of environmental variables such as fertility, locations, weather, insects, diseases, management,

compatibility with legumes, etc., have on the new synthetics. If more than one synthetic is evaluated, the best ones are chosen for animal evaluation trials.

Phase V. Seed increase. It is necessary to increase the amount of seed of the new synthetic so that grazing trials can be established.

Phase VI. Animal evaluation. Animal performance is used to evaluate the new synthetic(s). At the University of Missouri, animal performance is usually evaluated with grazing trials and in some instances feeding trials with hay.

Phase VII. Release and increase of seed.
Do all potential forage cultivars need to have animal data prior to release? The answer to this question is not immediately apparent. For example, one might conclude in developing a cultivar for only higher seed yields that animal evaluation may not be necessary. This is a dangerous assumption since the breeder may not be aware of changes in plant composition such as antiquality factors, mineral concentrations, etc., that may have an influence on animal performance. Also, if resistance for pathogens and insects is bred into a cultivar, the factors responsible for conditioning this resistance may also influence animal performance. For example, phenolic compounds have been reported to be synthesized by the host in response to fungal infection (Swain et al., 1979) and have been reported to be antibacterial agents. It is conceivable that these antibacterial agents could influence animal performance. Certainly, if the breeding objective for a cultivar is the improvement of a particular quality parameter, animal performance data are essential.

ANIMAL EVALUATION TRIALS WITH TALL FESCUE

Under grazing, differences in animal gain among forage treatments are a function of the amount of herbage available, its nutritive value, and the amount consumed by animals (Matches et al., 1983). To evaluate the forage quality of potential cultivars, herbage allowance per animal must be uniform among all treatments.

A grazing experiment was initiated in 1974 to compare a new University of Missouri tall fescue synthetic (experimental I-96 and later released as 'Missouri-96') with four other tall fescue strains. The primary objectives of the experiment were to determine if differences in animal performance could be detected among tall fescue synthetics using relatively small pastures, and to identify factors associated with differences in animal performance.

Five tall fescue synthetics, namely 'Kentucky-31', 'Kenmont', 'Fawn', 'Kenhy', and Missouri-96, were seeded into 0.47-ha pas-

tures at the University of Missouri's Southwest Research Center. The experimental design was a randomized complete block with three replications.

Hereford heifers which averaged 225 and 204 kg live weight at the start of grazing in 1974 and 1975, respectively, were used as testers. Grazing periods were approximately of 40 days' duration each for separate evaluations during the spring, summer, and fall. Pastures were grazed by three tester animals in the spring and fall and by two testers during the summer. Individual testers grazed the same cultivar all season, and between periods of evaluation, they grazed the same cultivar in a reserve pasture.

All pastures were strip grazed and stocked at the same grazing pressure. Therefore, the amount of herbage allowance was equal. The same herbage allowance was maintained by adjusting with electrical fences the area grazed dependent upon the amount of herbage available. The animals were allowed to graze each strip 7-10 days. Cattle were alloted (disregarding sward growth) a daily amount of herbage dry matter equivalent to 2.5% of their body weight. Weekly pasture samplings recorded the amount of herbage available before grazing and the amount of residue herbage remaining after grazing. No grain was fed in these pastures, but mineral and salt were available.

Significant differences were found ($P < 0.05$) in heifer average daily gains (ADG) among cultivars in the spring and fall for both years (Table 1). However, no significant differences were detected among cultivars for the summer period. The ADG's on Kenhy and MO-96 were over 40% greater than ADG on Ky-31 which is the cultivar most commonly grown in the southern corn belt. Herbage yield was significantly different ($P < 0.05$) among cultivars on a per ha basis in the spring and fall, but not during the summer.

Table 1.--Mean average daily gain (ADG) of heifers and estimated herbage intake on tall fescue cultivars in 1975-76

Cultivar	Spring		Summer		Fall	
	ADG	Intake	ADG	Intake	ADG	Intake
	kg/day					
Kenhy	0.74	3.95	0.34	5.88	0.65	6.06
Kenmont	0.50	4.02	0.27	5.54	0.44	5.95
MO-96	0.71	4.04	0.24	6.00	0.62	5.75
Fawn	0.48	4.11	0.30	5.68	0.45	5.90
Ky-31	0.51	3.96	0.18	5.54	0.45	5.76
Significance	**	ns	ns	ns	*	ns
Std. error	0.04	0.14	0.05	0.13	0.06	0.17

*, ** Significant at the 5 and 1% level of probability, respectively.

Intake was estimated by the difference between the herbage available at the start of grazing less the amount of residue remaining after grazing. In no case were there differences ($P < 0.05$) for intake among cultivars, and correlations between ADG and intake were low ($r = 0.11$ to 0.57). Weekly sward measurements confirmed that there were no differences among cultivars for rate of growth.

We do not know for certain why Kenhy and MO-96 have given superior ADG's. Quality analysis has shown in most cases that *in vitro* dry matter digestibility (IVDMD) is about the same for all cultivars tested. Occasionally, Kenhy will have higher IVDMD than Ky-31 or MO-96; however, it usually is not statistically significant. Neutral detergent fiber, acid detergent fiber, hemicellulose, lignin, cellulose, ash, and silica determinations have given little insight as well in explaining the ADG differences. Intake studies using hay showed slight increases for MO-96 as compared to Kenhy, Fawn, Kenmont, and Ky-31 (Martz et al., 1975).

ANIMAL EVALUATION TRIALS WITH ORCHARDGRASS

Two orchardgrass synthetics selected for general resistance to the stem rust pathogen *Puccinia graminis* Pers. f. sp. *dactylidis* Guyot de Massinot were evaluated in replicated grazing trials similar to what was described for tall fescue earlier. The grazing trial was conducted in the fall of 1982 and lasted 42 days. Average daily gains ranged from 0.68 to 1.02 kg/day (Table 2). MO-I and MO-II had the highest ADG's and gains/ha. The coefficient of variation for both ADG and gain/ha was 10.4%.

Histological studies conducted by Edwards et al. (1981) may explain the differences in ADG of the orchardgrass synthetics. Figure 1 contains the cross section of an orchardgrass leaf blade infected by *P. graminis*. The cross section was stained

Table 2.--Mean average daily gains (ADG) initial weights, final weights and gain/ha of steers on orchardgrass synthetics evaluated in the fall of 1982

Measurement	Synthetics[/]				
	MO-I	MO-II	Hallmark	Potomac	Sterling
Initial weight (kg)	209 a	209 a	204 a	209 a	208 a
Final weight (kg)	250 a	252 a	240 ab	244 ab	237 b
ADG (kg/day)	0.98 ab	1.02 a	0.85 abc	0.83 bc	0.68 c
Gain/ha (kg)	310 ab	325 a	268 abc	268 abc	212 c

[/] Numbers followed by the same letter are not significantly different at the 0.05 level as evaluated by the Duncan's Multiple Range Test.

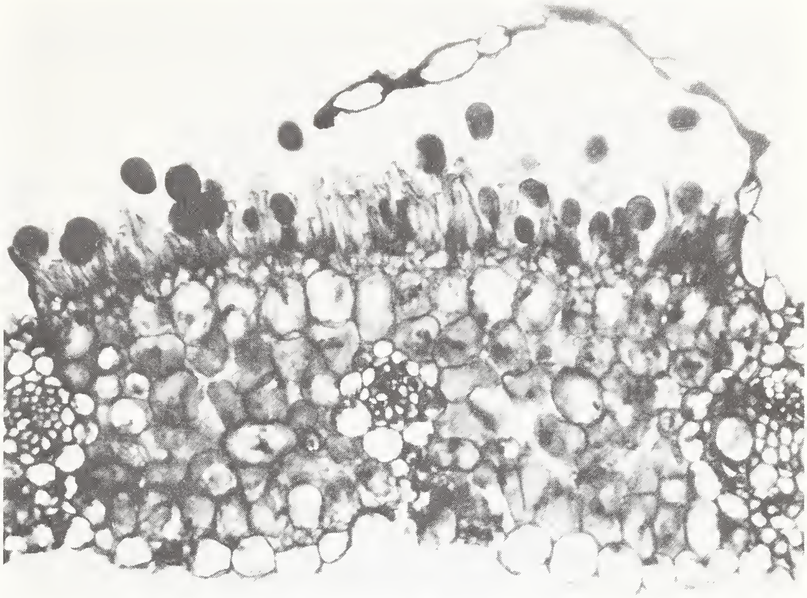

Fig. 1.--Cross section through a pustule of P. graminis f. sp. in an undigested orchardgrass leaf blade.

in safranin-fast green. Urediospores showed a positive staining for lignin and easily identified the underlying plant tissues in which mycelium occurred. The epidermal layer had ruptured during sporulation and was separated intact from the underlying mesophyll cells. When the infected tissue was placed in rumen fluid and later examined histologically, there was a lack in the amount of tissue digested as compared to the non-infected control (Fig. 2). The lack of digestion was not limited to tissues adjacent to uredia, but could be observed in tissues some distance away. This gives good evidence that this infected tissue is not digested and one may speculate that this would give lower animal performance.

It appears that the magnitude of ADG can be attributed to the level of infection by P. graminis. MO-I and MO-II had the least amount of infection while Sterling had the most.

In summary, animal trials are necessary before the release of forage grass cultivars. The kind and amount of animal data depends upon the species and upon the objectives for releasing a cultivar. Our objective was to release a cultivar with improved forage quality. Therefore, conducting grazing trials where the grazing pressure was constant was essential. We also feel that more than one location is desirable and that grazing experiments should be conducted for 2 or 3 years.

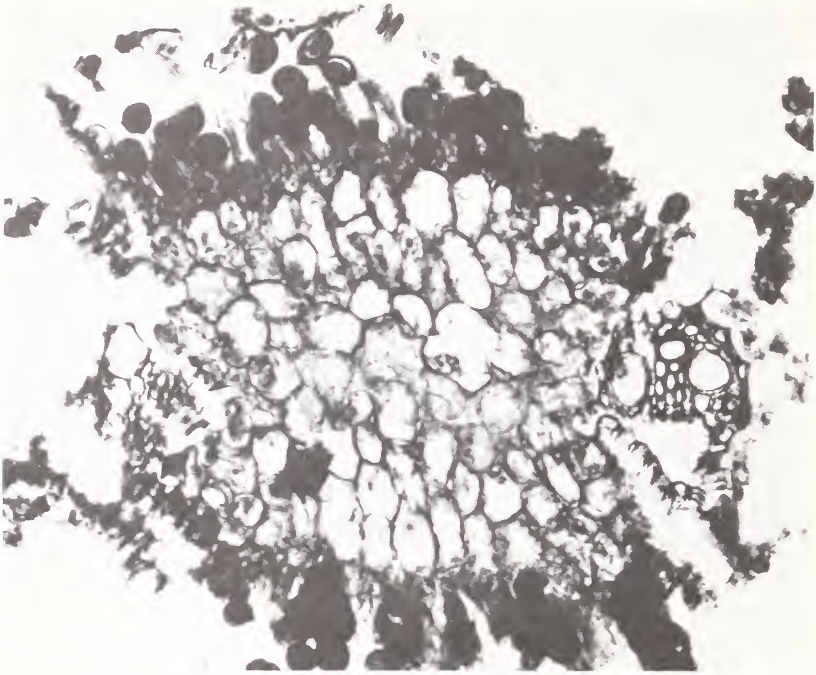

Fig. 2. Cross section through a pustule of *P. graminis* f. sp. *dactylis* in an orchardgrass leaf blade after 48 hours of digestion. Note lack of digestion in area associated with the infection.

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Panel Discussion: Data Required Before Releasing Forages. What Kind and How Much?

USDA'S PRACTICE AT TIFTON, GA.

Glenn W. Burton and Warren G. Monson

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At Tifton we have usually required a new cultivar to be equal to those in use in most traits and superior in one or more important traits such as yield or quality. This requires that selections with potential must be compared in various tests with checks of known performance. Their breeding behavior must be known. Such selections must be tested in the same form as the cultivar will be when it reaches the farm. For example, a 4-clone synthetic should not be tested in the Syn-1 generation unless like Gahi 1 pearl millet it can reach the farm in the Syn-1.

Information relative to a known check that we like to have about a selection before it is released as a cultivar may be outlined as follows:

1. Area of adaptation
2. Dependability
3. Ease of establishment
4. Persistence when utilized for hay or pasture
5. Pest resistance
6. Management requirements
7. Yield of dry matter and cow matter
8. Quality (palatability and digestibility)

Selecting the top forage requires precise effective screens for forage and seed yield, cold and drought tolerance, and disease and insect resistance. Estimates of forage quality that correlate well with animal performance are needed and have been supplied in our work with Monson's IVDMD test. We believe some grazing experience is desirable for every new cultivar that differs appreciably from a known check. Grazing experiments can supply this experience and may give differences that are statistically significant if they are large enough. Release of new cultivars should not be held up until complete

adaptation information is available but enough information relative to a check of known performance should be obtained to suggest where a new cultivar can be successfully grown.

Because potential new cultivars are frequently little better than those in current use and because the breeder's greatest asset, his credibility, is at stake when a new cultivar is released, he must do everything possible to improve the precision of his experimental tests. Soil heterogeneity in a test field can nullify the results of any cultivar evaluation test. To avoid this problem such tests should be placed in uniform fields based on uniform crop performance.

We have found that uniform pre-cropping with legumes such as velvet beans or soybeans for grass tests and with grasses such as pearl millet or small grains for legume tests is good practice. Perfect stands of the precrops is a must - otherwise they can do more harm than good.

We have found that methyl bromide fumigation is a good practice for spaced plant and small plot tests. It is expensive! Commercial application at Tifton is costing $1,000 per acre in 1983. However, it eliminates practically all weeds and greatly reduces soil borne pests. The reduced weeding costs probably cover most of the fumigation cost. More important, however, is the fact that fumigation makes the soil environment more uniform, permits rapid establishment of seeded plots and makes first year results meaningful. The year saved pays big dividends on the investment.

Machine fertilization can be more uniform than hand application if the best machines available are used properly.

We have found that lattice square designs can increase the precision of some yield trials a great deal. The 9 x 9 balanced lattice square test that we have used for testing the yield potential of experimental pearl millet hybrids has on the average doubled the precision of our tests. With the computer analysis of the data, such tests involve no more work on the part of the breeder than randomized block experiments.

Increased yield of animal product is usually the bottom line in any forage breeding program. Increased pest resistance, if significant, must ultimately result in increased yield of cow matter and probably dry matter. If yield can be increased in the presence of the pests, the higher yielding plants will probably be more resistant if the pests are affecting yield appreciably. The forage breeder must, therefore, continually search for new and better screens for forage yield.

Usually spaced plants with no replication must be screened first. This is the screen that must identify the top few plants in a population. Improving the uniformity of every

step from the seed to the field will pay dividends. We have our best technician transplant every seedling from flats to 2-inch clay pots. The 2-inch pots set in sand on a greenhouse bench give each seedling a uniform environment in which to develop. When large enough to be transplanted without loss of stand, the plants are removed from the pots and carefully set in our most uniform fields that have been precropped with velvet beans and have been uniformly prepared, fertilized, etc. With all of this and more, it is impossible to select the highest yielding plant in such plantings. Hopefully, a number of the highest yielding plants can be selected for replicated small plot tests.

With our perennial grasses, we have established small plot tests with clonal material that we usually start in pots in the greenhouse in the winter. These are then transplanted in sufficient numbers to small plots to give a coverage of a 2-foot wide strip before the first season is over.

In some of our bahiagrass research, we are interested in comparing the performance of different 2-clone hybrids in clipped plots. To produce enough seed for seeded plots would require at least one additional year and much extra work. Twelve seedlings established in the greenhouse in the winter and set 1-foot apart in the center of a plot will make a sod 2-feet wide before the season is over. Sixty seedlings of a cross can give 5 replications and producing so few hybrid seeds is easy. We have just concluded a 3-year clipping test with 10 entries with seeded plots and potted plant plots side-by-side with 5 replications. In this test, the potted-plant-plots established faster, yielded more the first 2 years, and when correlated with seeded plots gave r values of +.67, +.73, +.83 and +.93 for the 1st, 2nd, 3rd, and 3-year average yields. We believe such potted-plant-plot tests can be satisfactory for preliminary screening. Replicated small plot tests from direct seeding will be preferred at a later date when more seed is available.

We like the spaced-plant population progress (SPPP) test for assessing progress made in population improvement such as our RRPS breeding program with Pensacola bahiagrass. This test as we have developed it consists of single-spaced-plant plots replicated 100 times. The test is established from 100 potted seedlings chosen at random from each cycle of RRPS. The spaced seedlings are set far enough apart (.9 x .9 m) to permit them to express their yield potential the first year without competition. Yields are taken twice. Two years of using this test indicate that it maximizes the precision per plant tested and establishes significant mean differences not evident in other tests. It also gives the relative estimate of the genetic variance left in each population, information of value to the breeder and minimizes the land and resources required for the test.

At Tifton promising spaced plants of bahiagrass and bermudagrass are tested in replicated small plots for 3 years. Plot size for bahiagrass is 5 x 16 feet and for bermudagrass is 9 x 16 feet. Tests are replicated 5 or more times. Usually N at 200 lb/A/yr. + P and K are applied annually. Green yields are taken from 2 x 14 foot plots with a sickle bar mower usually 5 times per season. Forage from each plot is weighed green and is sampled for dry matter percentages. These samples are later ground and analyzed for IVDMD.

The following outline lists steps that we consider very important in measuring forage quality. A failure at any step can produce misleading results worth less than none at all.

1. Uniform plant growing environment
2. Uniform management
3. Uniform age
4. Representative sampling
5. Uniform drying (70^{o}C) and grinding
6. Active rumen fluid
7. Precise laboratory procedures
8. Careful laboratory technicians
9. Replication
10. Known performance checks

At Tifton, Georgia, the best entries in clipped plots have usually been grazed in replicated 2-acre pastures with 150 lbs/N/A/yr. plus P and K for 3 years before release to certified growers.

Region of adaptation information has been obtained by agronomists in other locations. Outstanding cultivars at Tifton have usually performed well at similar or warmer latitudes.

Panel Discussion: Data Required Before Releasing Forages. What Kind and How Much?

FORAGE QUALITY ASSESSMENT: IMPORTANT FACTORS FOR PLANT BREEDERS TO CONSIDER

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INTRODUCTION

The importance of forage quality assessment in plant breeding and evaluation programs has been readily recognized in the past decade, although such thoughts may have been somewhat heretical in the early 1960's (Johnson 1969). Progress has been made in what is now commonly called "multidisciplined" research where agronomists, animal scientists, pest managers and economists form teams to attack problems.

Hodgson (1981) suggested four questions to be asked concerning breeding and evaluation programs. They are:

(a) the reliability of relatively simple assessment procedures as predictors of the potential value of plant material for animal production,
(b) the relevance of the measurements to farming practice,
(c) the most effective way of incorporating the alternative procedures into a selection program, and
(d) the resources to be committed to the various stages.

Selection criteria usually include total production, nutritive value of the forage produced, the ability to establish easily, to withstand climatic stresses, to adapt to different management systems, to resist or tolerate pests and diseases, and to readily produce material for propagation (Burton 1970). A successful breeding program will incorporate many of the attributes listed above. The complexity clearly illustrates the impossibility of selection on "increased production" alone. Certain desirable characteristics are known to be limiting in certain species, such as digestibility in most warm-season perennial grasses. Breeding for improvement of such can improve animal performance. However, concentration on a particular trait can create its own problems such as lack of persistence under grazing among more digestible

varieties.

The emphasis of this paper involves animal consumption and utilization of nutrients contained in forages. Though deficiency of any one of the many nutrient factors required by animals may limit growth, lactation or reproduction to some degree, energy is the nutrient most frequently found lacking in forages. Even when deficient, most other nutrients can usually be easily and economically supplemented.

FORAGE QUALITY

The ultimate assessment of forages is animal production, either production per animal or production per unit of land. The nutritive value of a feed is the product of intake, digestibility and utilization (Raymond 1968). The common forages fed to ruminants have been evaluated much more extensively for energy content, digestibility and even utilization than for intake (Waldo 1969). Heaney (1969) suggested that combining digestibility and intake into a single index provides a means of evaluating the feeding value of forages more effectively than the evaluation of either alone. This index, if effective, should be highly correlated with average daily gain. Data are limited concerning this relationship though a few trials give reason for optimism (Crampton 1957, Lippke 1980).

When using digestible energy intake (DEI) as an index for forage quality, the relative contribution of intake and digestibility are not the same. Milford and Minson (1965) found that digestible dry matter intake (DDMI) of tropical grasses was more correlated with intake of dry matter than its digestibility. Crampton _et al_. (1960) reported that variations in intake accounted for 70 percent of the variability in the Nutritive Value Index. Crampton (1957), Osbourn _et al_. (1970) and Ventura _et al_. (1975) agreed that intake is the more important factor in determining quality, but intake of a given forage is more variable between animals than is digestibility (Blaxter _et al_. 1961, Minson _et al_. 1964, Heany _et al_. 1968). This variation among animals may be due to (1) animal weight (Heaney 1969); (2) fatness (Bines _et al_. 1969); (3) physiological rumen volume (Purser and Moir 1966); and/or (4) retention time of organic matter in the rumen (Campling _et al_. 1961, Hungate 1966). The importance of voluntary intake however does not imply that digestibility is not important in determining DEI or other expressions of quality. Blaxter _et al_. (1961) calculated that under _ad libitum_ feeding conditions, a change in digestibility of DM from 50 to 55 percent resulted in 100 percent increase in weight gain.

Much work has been done attempting to relate chemical compo-

sition of forages to forage quality. Low protein content has been considered the limiting factor in controlling feed intake (Milford and Minson 1965). However, this generally occurs only when crude protein (CP) content of the forage falls below 6-7% of the DM (Minson and Milford 1967). Above this "critical level", rumen fill is considered the primary determinant of intake in ruminants (Campling et al. 1961, Conrad 1966) especially with lower quality forages (Fig. 1). When digestibility reaches 65-70%, then control of intake by rumen capacity yields to chemostatic or thermostatic controls (Montgomery and Baumgardt 1965, Blaxter *et al*. 1961). Since few forages have digestibilities in this range, we are mostly concerned with rumen distension or fill.

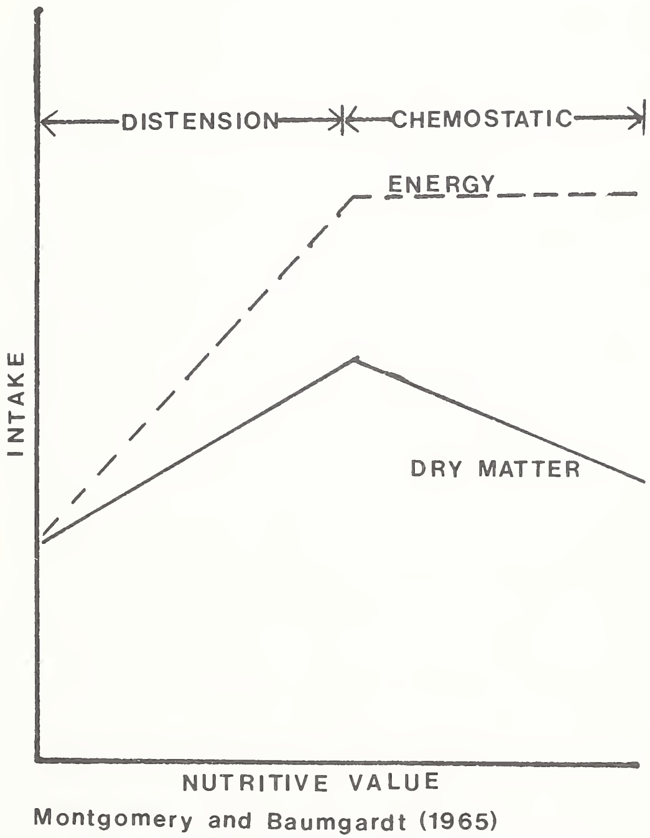

Figure 1. Theoretical relationship between nutritive value (digestibility) and intake.

Basic to the problem of using cell wall constituents (CWC) to predict forage quality is the fact that CWC, or any other representative of the fiber portion, fails to manifest itself as a nutritionally uniform fraction (Lucas _et al_. 1961). In general, ideal fractions are either completely digestible or essentially indigestible (Van Soest 1969). No ideal fractions exist which show a partial digestibility. Perhaps physico-chemical factors such as encrustation, lignification, crystallinity of cellulose and the organizational structure of the forage cell wall fraction will yield some insights into the determination of forage quality. Much attention has been given to the effects of physical form such as grinding and pelleting on nutritive value and animal performance. Excellent reviews have been published by Minson (1963), Putman and Davis (1961), Beardsley (1964) and Moore (1964).

Several factors other than chemical and/or physical properties of the plant are involved in forage intake by grazing animals. Digestible dry matter intake can be quite variable, especially of warm season or tropical grasses, due to heterogeneity of the sward, seasonal production and variation in sward or canopy structure (Chacon and Stobbs 1976). Ruminants have an enormous task of harvesting 40-60 kg of fresh feed daily and the special distribution of leaf within the sward or canopy influences the ease with which the animal can satisfy its appetite. With leafy temperate pastures, animals can consume large mouthfuls and can satisfy their appetite rather easily in 6-8 hrs/day (Stobbs 1973). Cattle graze warm season pastures for a longer time each day than temperate pastures even when large quantities of herbage are available for grazing (Stobbs 1974). Time available for grazing is limited by need for rumination and other factors. Furthermore, rumination time is longer for warm-season forages than for temperate forages. Thus, the structure of the sward, especially the verticle leaf density and its ease of prehension become important factors to consider if the new release is to be used primarily for grazing.

TECHNIQUES

Reid (1966) in a review discussed the "state of the art" of forage evaluation. At that time, _in vitro_ fermentation procedures were gaining acceptance for estimating digestibility and Van Soest had completed his series of articles describing chemical fractionation of feeds. No laboratory technique was available for adequately estimating intake. Now, seventeen years later, the "state of the art" is approximately the same. The need to know the parameters previously discussed makes necessary a screening technique which can be used for many samples. It must be fast, routine, require very small amounts of sample and precisely predict the parameter of interest.

The cell wall fraction constitutes the structural part of the plant and is the least digestible and most slowly digestible portion. Thus, it determines the space-occupying capacity of a forage or feed (Van Soest 1965), and should afford the best predictor of intake. Van Soest (1965) reported results from 82 forages (six plant species) in which intake was correlated with various chemical components. Total correlations over all species showed CWC to be best related ($r=.65$, $P<.01$) to intake. Correlations with intake of all components (lignin, acid-detergent fiber (ADF), protein and cellulose) were similar within species indicating the uniform influence of maturity on forage quality. However, between species correlations were more variable. Regression analyses indicated the relationship between intake and CWC was curvilinear with the influence of CWC being markedly depressed when CWC constitutes less than 50% of the DM. This suggests that CWC, representing the total fibrous part of the forage, limited intake when the proportion of these constituents increased to more than 55 to 60% of the dry matter. These relationships are consistent with observations regarding the existence of a point in the intake-fiber mass relationship where fiber mass ceases to affect intake (Conrad _et al_. 1964, Montgomery and Baumgardt 1965).

Digestibility

The recognition of the importance of the digestibility of a given forage by ruminants led to development of the two-stage _in vitro_ technique (Tilley and Terry 1963). Application of this technique has enabled systematic studies of factors influencing digestibility of forages such as variation between species and varieties, and estimation of genotypic variation and heritability. The improved precision and acceptability of the technique over prediction from chemical analyses (Table 1) added a whole new realm of selection criteria in breeding programs. Unfortunately, the technique is not without flaws, some of which are maintenance of a donor animal, variability in the potency of the rumen inoculum from run to run, and interactions across some species due to different digestion rates. The last two can be partially overcome by donor diet standardization and inclusion of standards of known _in vivo_ digestibility.

Two techniques have been used which have theoretical advantages over the typical _in vitro_ system. Kapp _et al_. (1979) suggested lyophilized rumen fluid as an alternative to freshly removed inoculum. Their results showed some differences in digestibility among sorghum grain, corn grain and alfalfa hay. However, rank in digestibility was not affected by lyophilization.

Cellulolytic enzymes have also been suggested as digesting

Table 1.--Relationship of laboratory techniques to digestibility of forage samples

Method	N	R^2	Std. Error Estimate	References
Acid detergent fiber	122	.22	5.3	Van Soest et al. (1978)
Acid detergent fiber	30	.07	5.6	Laredo and Minson (1973)
Neutral detergent fiber	30	.06	5.5	Laredo and Minson (1973)
Lignin	30	.20	5.1	Laredo and Minson (1973)
Lignin[a]	15	.81	2.3	Laredo and Minson (1973)
IVDMD[b]	36	.92	2.2	McLeod and Minson (1973)
Near infrared	76	.95	2.5	Norris et al. (1976)

[a]Stem only.
[b]In vitro dry matter disappearance (Tilley and Terry 1963).

agents. Jarrige *et al.* (1970), Jones and Hayward (1973), and McLeod and Minson (1978) obtained good correlations between *in vivo* and cellulase digestibility though earlier attempts at using cellulolytic enzymes met with little success (Donefer *et al.* 1963). Rees and Minson (1976) observed that *in vitro* techniques were biased when used to estimate digestibility of grasses grown with various levels of sulfur fertilizer. Both rumen fluid-pepsin and pepsin-cellulase resulted in bias. No doubt there are other environmental factors which may uniquely influence plants in such a way that laboratory techniques give biased estimates of animal data. However, provided researchers are aware that such potentials exist and insure the procedures are used within the range of genetic and environmental conditions for which they have been tested for they can provide ranking as well as estimates of actual digestibility for forages.

Near infrared reflectance spectroscopy offers a rapid, nondestructive technique for estimating chemical and biological parameters of forage quality, including digestibility. Extensive work has been conducted to calibrate NIR for chemical quality estimates of temperate forages (Shenk *et al.* 1976) but only limited work has been done with warm-season forages (Burdick *et al.* 1981, Coleman *et al.* 1982).

Intake

Though the *in vitro* technique for estimating digestibility has been widely received and used and much progress in quality of forages has been realized, little has been accomplished to incorporate an estimate of intake into forage quality assessment. One of the problems of assessing intake is the inherent animal variability and bias due to class and status of the animal. Intake assessment could very well lead to greater improvement in warm-season forages than digestibility assessment due to their high fiber, long residence time and slow rate of digestion as compared to temperate species. Rate of digestion and rate of passage are important factors relative to mechanisms which control intake (Waldo *et al.* 1972), but they are not causative agents. Several efforts have been made to identify or characterize the causative agents. Balch (1971), Sudweeks *et al.* (1975) and Welch and Smith (1969) suggested that rumination time or time spent chewing was related to fibrousness or coarseness of roughages. Welch and Smith (1969) found a significant correlation (r = .99) between minutes of rumination time and CWC intake. These results suggest that some factor other than presently known chemical fractions influences rumen fill which in turn influences intake. Lignin content per se probably has little effect on extent of digestibility, but the amount of lignified (encrusted) tissue was implicated as being very important from microscopic evaluations (Akin *et al.* 1974, de la

Torrie *et al.* 1974). The lack of influence of lignin content has long been suspected as a result of comparing digestibility of legume vs grass species. The understanding of physical characteristics of forage plants which influence rate and extent of digestion, particle size reduction and rumen clearance rate is necessary to be able to predict intake using inexpensive laboratory methods.

Rapid, precise laboratory techniques related to intake are needed which require only a small sample. A few potential techniques are listed in Table 2. Small ruminants such as meadow voles or blue duikers (Cowan *et al.* 1976) have been proposed to estimate both intake and digestibility. However, more forage is required (approx. 2 kg) than most plant breeders harvest from individual nurseries. Perhaps one of the most successful tools to date is a grinder supplied with a wattage meter to measure the power required to grind a given amount of the forage in question (Laredo and Minson 1973; D. I. H. Jones, personal communication). Scientists at the Welsh Plant Breeding Station routinely used the instrument to estimate intake of their plant breeding material. An earlier approach was artificial mastication (Troelson and Bigsby 1964). They found a high correlation (r = .94) between "particle size index" after mastication and intake/100 lb. body weight of sheep. Though NIR has potential as a technique for estimating intake, essentially no data have been published relating intake to near infrared spectra, due primarily to the difficulty in obtaining sufficient samples of known intake. One might expect interactions with predictability and forage type similar to those shown by Moore (1977) when intake and digestibility of tropical forages were predicted from chemical components using equations from temperate forages.

GRAZING

Hodgson (1981) writes "It would seem to be an article of faith that any plant material intended for use under grazing conditions should be selected and tested under such conditions, or at least by procedures which have been shown to provide a true index of performance under grazing. The comparative assessment of pasture plants in terms of animal production is a major undertaking, and it is unlikely ever to be realistic to subject more than a small number of the most promising genotypes to trials involving practical systems of animal production".

Grazing produces a very complex situation where several dynamic processes interact with one another. The defoliation and trampling process of the animal influences plant growth and persistence. Therefore, plants with prostrate growth and high tiller population are most suitable characteristics for

Table 2.--Relationship of intake of forage to laboratory analytical techniques

		Intake, $G/W^{.75}$					
Method	N	Species	Mean	SD[a]	R^2	Std. Error of Estimate	References
Artificial mastication	14	Sheep	49.5	4.3	.88	1.86	Troelson and Bigsby (1964)
Grinding energy	30	Sheep	48.7	--	.63	8.2	Laredo and Minson (1973)
Bulk density	30	Sheep	48.7	--	.49	9.7	Laredo and Minson (1973)
Acid detergent fiber	12	Sheep	51.7	6.9	.66	5.2	Lippke (1980)
Neutral detergent fiber	12	Sheep	51.7	6.9	.09	--	Lippke (1980)
Near infrared	21	Cattle[b]	--	--	.72	9.6	Ward et al. (1982)
Near infrared	76	Sheep	--	--	.62	7.8	Norris et al. (1976)

[a]SD = Standard deviation of mean of animal data.
[b]Grazing with total fecal collection.

grazing (Hodgson 1981). However, erect plant types appear to increase efficiency of harvesting incident light. On the other side of the coin, plant growth habits and the resulting vertical distribution of bulk density may influence harvesting efficiency by the animal. Rate and type of plant growth influence how much is eaten, what is eaten and how much is trampled (Chacon and Stobbs 1976) whereas each of the above influence growth rate, tiller production and canopy structure.

Once the germplasm has passed through several steps and only a few superior types are left, feeding and/or grazing trials may be appropriate. Before animal data are collected, the influence of the grazing animal on the forage in question should be evaluated in very small plots. Sheep are excellent animals for this since they graze closer and would put greater pressure on persistence, regrowth potential etc... than would cattle.

In summary, quality evaluation is an important factor before forages are released. Evaluations can be made in different ways depending on the "stage" of evaluation progressing from simple laboratory predictive procedures to full scale feeding and grazing trials.

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Panel Discussion: Data Required Before Releasing Forages. What Kind and How Much?

GRAZING MANAGEMENT AND UTILIZATION RESEARCH PRIOR TO RELEASE OF PASTURE CULTIVARS

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To paraphrase Shakespeare, "to cut or not to cut - that is the question". Plant breeders have commonly evaluated potential pasture cultivars with various types of mowing machines, often obtaining little or no grazing data before release of a cultivar. There is a good reason for bypassing the grazing animal - it takes time, requires more seed, and is expensive.

This topic was addressed in depth by Australian and USA scientists in a Forage Evaluation and Utilization Workshop at Armidale, New South Wales, Australia in October 1980 (Wheeler and Mochrie) where they "agreed quite clearly" that:

> "Forages should not be released for public use until they have been evaluated with animals."

If this rule had been applied to forage cultivars in the past, many would never have been released. Today, more plant breeders in public agencies are evaluating their cultivars with animals but less of this is done in private companies.

Before we make a judgement of the breeders, it is important to recognize that breeders of forage cultivars have many objectives:

1. Resistance or tolerance to pests such as nematodes, insects, or diseases.

2. Seasonal forage distribution such as improved winter production.

3. Improved nutritive quality. This may include reduced lignin, reduced alkaloid or tannin levels, and increased mineral content.

4. Tolerance to unkind soil conditions such as high aluminum or manganese in acid soils, low soil phosphorus, or poor drainage.

5. Tolerance to livestock trampling.

6. Competition with other species.

Obviously, some of the above items are not directly related to grazing of livestock. Why then do we need grazing data before release of forage cultivars?

1. A grazing animal is not the same as a mowing machine. This may seem so commonly known that it needs not be mentioned, yet many scientists forget that the grazing animal has special effects on pasture plants. The grazing animal exercises selectivity for desirable plant parts such as leaves and for individual species in a mixed sward. Grazing animals may tear rather than cut the herbage. In addition, there is a pulling effect which may be especially severe on the plant when it is young. The trampling effect of hooves puts enormous weight on small areas, compacting the soil and crushing plant parts. Livestock graze during wet as well as dry weather, causing pugging of pastures which can be more severe on one plant species than another. Grazing usually results in frequent defoliation as contrasted to the mowing machine which allows periods of recovery between harvests. The frequent defoliation in a pasture is often most severe during period of limited growth during winter. Grazing animals also defecate and urinate on a pasture, something not done by a mowing machine.

2. Dry matter production over the growing season is not directly proportional to stock carrying capacity or animal production produced. Changes in temperature and rainfall change yield and quality throughout the year. The mowing machine cannot really evaluate the amount of animal product produced, even with forage quality evaluation.

3. Anti-quality components of the forage complicate the picture. Alkaloids in some grasses and lupines reduce animal performance or make the forage unpalatable. Low levels of tannin in legumes such as trefoil and arrowleaf clover reduce bloat potential but high levels of tannin in sericea lespedeza reduce digestibility of both dry matter and crude protein. Glucosides in sorghums and fungal endophytes of tall fescue also may result in reduced livestock performance. Levels of these components may be determined in the laboratory but their practical importance is often modified within the rumen.

4. Persistence under grazing and encroachment of other species can be very different when grazed than mowed. The amount of leaf tissue removed, effect on root or crown carbohydrates, and tillering is often quite dissimilar under grazing and cutting, thus affecting persistence.

5. Seasonal distribution of growth is better evaluated with animals than with a mowing machine. The lag time required for harvesting and sudden removal of harvested forage often interact with weather conditions to affect forage growth rate.

6. Grazing trials can help "sell" a new cultivar if it really is superior. Producers are far more impressed with animal performance than they are with forage yield data from small plots.

If grazing is to be used in evaluating cultivars, how should grazing studies be conducted on new cultivars? This is a complex area and only a few suggestions are offered in this brief discussion:

1. Animal preference studies are low priority as the grazing animal's preference rarely has biological significance when the animal is forced to eat the less preferred species. Cattle do not like sericea lespedeza, yet when confined to it, they will perform satisfactorily. Alfalfa, a top quality forage, may be ignored by cattle initially when put pastures of this species as they search out weedy species such or chickweed.

2. Cultivars should be grazed in trials as they would be under normal farm conditions unless a special grazing method is to be recommended.

3. Grazing should be done with the kind of animals expected to be carried by farmers on this pasture cultivar. Sheep grazing of experimental cultivars may reduce the cost but results may not easily be transferred to predict cattle performance and effects of grazing on the cultivar.

4. Comparisons should be made with standard cultivars in replicated grazing experiments over several years.

5. Observational on-farm grazing trials in cooperation with extension forage and animal science specialists can be useful in evaluating persistence, reseeding, and other characteristics. Also, these trials may be useful in convincing the extension specialist that the cultivar is good and should be promoted. This method is commonly used by private companies as it is low-cost and offers the advantage of promoting the cultivar.

SUMMARY

Do we always need animal grazing data before release of a pasture cultivar?

1. Cutlivars of species new to the area or from exotic germplasm quite different from existing cultivars or selected for improved nutritive quality should always be subjected to grazing by livestock before release to the public.

2. It can be argued that there is a lesser need for grazing data if the new cultivar was selected for pest resistance, is a well-established pasture species, has no anti-quality problems, and plant morphology has not been changed. The danger with this approach is that in selection for one trait another may have been altered and so affect animal performance. Thus, grazing of potential cultivars before release is the safest approach to avoid a potential problem.

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Panel Discussion: Data Required Before Releasing Forages. What Kind and How Much?

STATE AGRICULTURAL EXPERIMENT STATION POLICIES

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Dr. Bouton asked that I address the topic "Data Required Before Releasing Forage Cultivars for Grazing - What Kind and How Much?", from an experiment station administrator's viewpoint. Rather than present only my own thoughts and ideas or the policy of the South Carolina Agricultural Experiment Station, I chose to get input from my colleagues in the Southern Region. To accomplish this, a questionnaire that could be answered in most cases by a "yes" or "no" was developed. The 15 questions were designed to get a broad view of the policies and procedures involved in releasing cultivars, germ plasm and breeding lines. The questionnaire was mailed to the directors of the agricultural experiment stations in the 13 southeastern states. All of them responded but due to their particular situations, did not answer all questions completely. A summary of the information obtained from the questionnaire is the basis for my comments.

Formal policies for release of germplasm exist in all but two of the southern experiment stations surveyed; only two do not have a formal policy regarding the release of breeding lines developed by the experiment station; while all but one have a formal policy for the release of cultivars. Within the southern states, however, the policies are implemented a bit differently. In Arkansas, for example, each release is handled in a manner consistent with the agricultural experiment station mission. The kind of germplasm (i.e., plant species) determines the exact process of release. In Louisiana, release is requested by the plant breeder through the department to the director. An ad-hoc committee is appointed by the director to review the data and to make recommendations. If the committee recommends release, the director prepares a release statement and appropriate publicity. Oklahoma, on the other hand, has a rather standard, but unwritten, policy.

Most of the experiment stations have a mechanism for the free exchange of germplasm in both the private (64%) and public

(85%) sectors. Four stations, however, will not freely release germplasm among breeders in the private sector while two will not exchange germplasm among breeders in the public sector. At six stations the free exchange is curtailed in the private sector and at two stations the exchange is curtailed in the public sector during some stage of development.

In Alabama, the exchange is curtailed when the line begins to look very promising and is breeding true for a trait. In Kentucky, germplasm may be released similar to cultivars but requirements are less stringent. Louisiana curtails exchange just prior to release of variety, while Mississippi curtails the exchange near the level of development suitable for varietal or germplasm release. In North Carolina, exchanges with the private sector are made as formal germplasm releases. Within the public sector, breeders may freely exchange material at any stage of development, with their counterparts in other public agencies. In Oklahoma, free exchange occurs after official release, except for rare "exclusive" releases. In Tennessee, advanced breeding lines are not exchanged with the private sector.

About 80% of the experiment stations have a procedure for the exchange of cultivars in the private and public sectors. Some of these procedures, however, are informal.

In testing experimental cultivars before release, all stations require multiple locations within the state. Half of the stations require out-of-state tests. All of the stations require tests over more than one year. Only two states do not require that the experimental cultivar be tested as a hay/silage crop; one state does not require simulated grazing and one state does not require in vitro analyses. All of the states require reaction to grazing be tested, as well as animal performance, nutrient analyses, and proximate analyses.

All of the experiment stations have a cultivar release committee which reviews release proposals and supporting information. In determining if the cultivar merits release, all of the states consider yield, persistence, resistance, area of adaptation, quality measurement, and undesirable traits. Only one state does not require a statement of intended use. One state does not consider a plan for seed or planting stock increase. Two states do not consider origin, breeding procedure, cultivar description or uniqueness in the decision. All of the states require superiority over available cultivars for one or more traits. Only three stations said that they would release a cultivar that is not superior for any trait. Alabama would release such a cultivar if a wider gene base was desirable. Louisiana would release one if the seed were not available from the public or private sector, while Mississippi would release the cultivar if the origin of the variety adds to a wider genetic variation and decreases

"genetic vulnerability" of the crop as a whole. In Mississippi, this would be an exception rather than the rule.

All of the experiment stations use a foundation seed organization for release of cultivars. In only two instances, however, is this foundation seed organization controlled by the experiment station. Only one state would not grant exclusive release to a private concern, while two states would not grant non-exclusive release to a private concern. The person who arranges for exclusive release varies by state, however. In Alabama, the breeder arranges for release after the variety release committee approves. In Arkansas, the researcher releases the cultivar through the director with advice of legal aides. The Florida Foundation Seed Producers, Inc. arranges release with the IFAS Cultivar Release Committee. In Kentucky, the seed committee of the Agronomy Department releases the cultivar with approval by the dean of agriculture. In Louisiana, Mississippi, Oklahoma, and Tennessee, release is accomplished through the experiment station. In North Carolina, the NC Agricultural Research Service develops a contract or Memorandum of Agreement with a private concern. In South Carolina, the South Carolina Foundation Seed Association arranges release. Virginia advertises for bids. Accepted bid must be approved by the department head and experiment station director.

The criteria used to select the private concern receiving an exclusive release also varies by state. In Arkansas, it may be done by a bid process or as a sole source release, while in Kentucky, the ability to produce and market the seed are primary criteria. Louisiana usually selects on a bid basis. In Mississippi, the criteria require a private concern to have the ability, dependability, and recognized integrity to produce and supply adequate amounts of high quality seed to users at reasonable cost. Policy of the Mississippi Agricultural and Forestry Experiment Station is to get seed of improved varieties to farmers at the lowest possible cost to farmers. South Carolina relies on the SC Foundation Seed Association to make the selection. In North Carolina, a private concern must have the capacity to increase seed and to make a commitment to provide reasonable quantities of seed to farmers at a reasonable cost. In Oklahoma, selection is based on a company's track record for sales, and whether the agricultural experiment station thinks they will push the variety. In Tennessee, company interest in the variety along with marketing capability in the area are the main criteria. Virginia selects the company with the most experience in producing seed of the crop and with the best mechanism for merchandising seed in the area of adaptation.

Only two states usually make exclusive releases of cultivars. Seven states seldom make exclusive releases, and three states never make exclusive releases. Among the states that do make

exclusive releases, various factors underlie that decision. In Alabama, market and product development are behind this decision, while in Arkansas, the economic potential of variety, its potential appeal to seed producers, and value of the cultivar to the agricultural interests of the state are prime determinants. Kentucky uses exclusive releases to provide a continuing supply of seed to the farmer, while Louisiana grants exclusive release to insure that seed or variety will receive proper promotion and get in the hands of producers in instances where public release probably would result in no interest by a large number of private breeders. Mississippi believes that development, marketing and use by producers could only be successful through exclusive release. If volume of potential demand is insufficient to attract participation by industry through a general release, exclusive release is usually the only viable alternative. This principally applies to new varieties produced from seed and not through vegetative stock. North Carolina uses the exclusive release procedure only when it appears to be the only or best means of providing growers the materials developed by the NC Agricultural Research Service. South Carolina considers exclusive release when the possibility exists of the cultivar not being promoted or marketed through normal channels. In Tennessee, exclusive release occurs for species for which state foundation seed organizations cannot produce seed. Virginia uses exclusive release when this is the only method of assuring adequate seed production and merchandising; usually for crops where seed must be produced outside the state. Texas uses exclusive release to maximize public benefit and to assure that the cultivar gets used.

Only two states do not receive royalties or payment when they make an exclusive release to a private concern and only three states report that they receive no royalties or payments for a non-exclusive release. On the other hand, only one state receives royalties or payments when the cultivar is released through a foundation seed organization.

In summary, the agricultural experiment stations in the southern region require that experimental forage cultivars be tested at multiple locations within the state and in multiple years before they are released. Testing includes reaction to grazing, animal performance, nutrient analysis, proximate analysis, and in most cases, performance as hay/silage, simulated grazing and in vitro analysis. Factors considered in release of forage cultivars at all stations are yield, persistence, resistance, area of adaptions and undesirable traits. Other factors considered by at least 75% of the states are origin, breeding procedure, cultivar description, statement on intended use, uniqueness, and plan for seed/stock increase.

COMPOSITION AND RUMINAL AVAILABILITY OF SULFUR IN COOL-SEASON GRASSES

B. P. Glenn and D. G. Ely

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The availability of sulfur (S) from forages consumed by the ruminant is dependent on forage S, ruminal S and the interactions with nitrogen (N) compounds in the forage and rumen. Supplementation to tall fescue with elemental S increased total S digestibility, retention and abomasal protein S recovery by wethers (Glenn and Ely, 1981a and 1981b). Supplementation with nitrate N tended to reduce N and S retentions and increase abomasal nonprotein S recovery. These data suggest the total S to total N ratio in forages may not be as important in defining ruminal degradability as are relative amounts of different forms of forage S and N. The objective of the studies summarized herein was to measure effects of forage composition on ruminal availability of forage S.

Tall fescue (*Festuca arundinacea* Schreb.) and orchardgrass (*Dactylis glomerata* L.) were fertilized with 3 rates of N (0, 100 and 300 kg/ha) and 2 rates of S (0 and 150 kg/ha) in a randomized complete block design with 4 replications per treatment. Forage N and S composition and ruminal N and S disappearance from forages were measured in samples obtained at 5 dates from April 17 to June 27 (Glenn *et al.*, 1980). Nitrogen fertilization increased total N, nonprotein N and protein N content (mg/g forage) of both grasses. In spite of similar total N concentrations, nonprotein N content was higher for tall fescue than orchardgrass. Protein N was higher for orchardgrass than tall fescue. Nitrogen fertilization reduced total S and nonprotein S concentrations (mg/g forage) and increased protein S content of both grasses. Sulfur fertilization increased all forage S components. Nonprotein S concentrations tended to be higher in tall fescue but protein S was higher in orchardgrass compared with tall fescue. Total N content was negatively correlated with nonprotein S content (tall fescue $r = -.53$; orchardgrass, $r = -.31$; $P<.001$). Nonprotein S content was negatively correlated with nonprotein N content (tall fescue, $r = -.27$;

Table 1.--Disappearance of Forage Sulfur (%)

Item	Fertilizer treatment ON-OS	ON-150S	300N-OS	300N-150S	SE
Sulfur			Tall fescue		
Soluble	68.7	76.0	37.4	56.8	1.3
Insoluble	14.4	10.9	37.0	25.0	1.8
Total, 24 hr	83.1	86.8	74.4	81.8	
			Orchardgrass		
Soluble	64.9	71.3	26.0	43.0	1.3
Insoluble	20.0	17.3	42.5	32.1	1.8
Total, 24 hr	84.9	88.6	68.5	75.1	

orchardgrass, $r = -.53$; $P<.01$). Total nonprotein amino acid concentration was greater in fescue while total hydrolyzable amino acid content was greater in orchardgrass. Orchardgrass may utilize available S and N for plant protein synthesis more effectively than tall fescue due to either different nutrient requirements or more efficient nutrient metabolism.

Ruminal N and S disappearance from the fertilized tall fescue and orchardgrass was measured by the nylon bag technique in rumen-fistulated steers. Water-soluble nutrient disappearance was measured as the initial 0-hr nutrient loss from forages in bags immersed in water and was correlated with loss at 6 hr (N, $r = .88$.; S, $r = .99$). Subsequent insoluble disappearance occurred in situ for 24 hr and was calculated as the difference between disappearances at 24 and 0 hr. Soluble dry matter, N and S disappearances (%) averaged 34.9, 45.3 and 59.7 for tall fescue and 27.4, 30.9 and 51.3 for orchardgrass, respectively. Extent of forage N disappearance at 24 hr was highest from grass fertilized with 300 kg N/ha and no S (81.1% from tall fescue and 76.4% from orchardgrass). Large differences in forage S disappearance were noted due to fertilization (see table 1). Sulfur fertilization increased extent of forage S disappearance. Extent of forage S disappearance at 24 hr was lowest from grass fertilized with 300 kg N/ha and no S.

Soluble S disappearance from forages was negatively correlated with total N and nonprotein N concentrations in forage and positively correlated with total S and nonprotein S concentrations. Greater losses of the rapidly soluble N and S from tall fescue than orchardgrass were a result of higher concentrations of nonprotein components in tall fescue.

Altering ruminal solubilization of S from forage may affect microbial uptake of the solubilized or available forage N and S. Established tall fescue and orchardgrass plants were

transferred from soil and maintained hydroponically in four nutrient solutions containing 2 rates of N (0 and 268 ppm) and 2 rates of S (0 and 134 ppm)(Glenn et al., 1981c). Changes in forage N and S components were similar to those seen in the field study. Solutions were treated with S-35 and labeled grass was harvested. Percent of the total absorbed S-35 which was absorbed into shoots were 29.4, 78.4, 29.1 and 69.7 for tall fescue and 9.0, 60.5, 53.4 and 55.0 for orchardgrass treated with ON-OS, ON-134S, 268N-OS and 268N-134S, respectively. Grasses were incubated in ruminal fluid in a closed, batch system. In vitro H_2S production and percentage of grass radioactivity recovered as H_2S and microbial protein were higher for grass treated with ON-OS and ON-134S compared with high N treatments. Grass S incorporation into microbial protein was calculated according to a modification of the equation by Walker and Nader (1968). Rate of grass S incorporation (µg/g grass/hr) after 60 min of incubation was 79, 117, 14 and 83 for tall fescue and 59, 100, 16 and 133 for orchardgrass. Rate of microbial protein synthesis (µg CP/g grass/hr)(60 min) was 5447, 8059, 926, 5713 for tall fescue and 4040, 6878, 1090 and 9157 for orchardgrass. Sulfur fertilization of cool-season grasses may have increased total S and nonprotein S solubility and uptake into microbial protein in the rumen. Furthermore, levels of N fertilization used for grasses may reduce solubility and extent of forage S disappearance and limit microbial use of S for protein synthesis.

Further research is needed to define forage protein and carbohydrate fractions that will predict efficiency of use of forage S and N in the gut to improve ruminant production from high dietary forage inputs.

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KOCHIA--FORAGE OR WEED?

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Kochia scoparia is a warm season annual forb best adapted to the drier areas of the Great Plains states from North Dakota through Texas. It is considered as serious weed pest in both rowcrop and small grain cropland but it has also been used for grazing (after small grain harvest) or an emergency hay crop in years of grain failure. These uses have been common for over 50 years.

A 1947 report from South Dakota State University showed first cutting kochia to be adequate for wintering beef heifer calves. They gained .95 lbs per day on kochia compared to 1.8 lbs per day on alfalfa hay. Feeding second cutting kochia caused the heifers to lose weight.

Texas Tech (Lubbock) research found kochia production going from 1.5 tons per acre on May 29 to 5.0 T./A on July 14 with a corresponding drop in crude protein from 25% to 13%. Yields of irrigated kochia at the Clovis, New Mexico Plains Branch Station of 12.5 tons per acre have been produced by H.D. Fuehring, NMSU. Water and N were not limiting factors. Protein levels ranged from 9.3% in June to 6.9% in August. These yield data indicate that 30 to 60 lbs of N are required for one ton of dry matter production.

Oxalate content in kochia appears to be about 7.0%. Oxalate can crystallize in the liver and kidneys of animals restricted to a diet of kochia for 60-90 days. Death has been reported within 60 days. Changing the diet appears to alleviate the problem.

Alleleopathy to subsequent crops is apparently significant. At Clovis, sorghum following kochia yielded only 1600 lbs per acre when irrigated six times. According to Fuehring, the sorghum plants showed water deficiency stress within a short time after irrigation. Wheat yields were also reduced. The

alleleopathic compound(s) are leachable from the soil within one year.

In western Oklahoma, kochia has long been recognized as weed in cropped areas but it has also been used for grazing in dry areas after wheat harvest. It has been tried as a planted forage crop in eastern Oklahoma (40"-50" rainfall area). Moderate success was achieved by one producer in 1980, a very dry summer. In 1981, this producer and several others had no success.

As kochia becomes more mature it may become unacceptable to grazing animals. R.L. Dalymple, Noble Foundation, Ardmore, Ok. used kochia as one forage species in an alternating grazing program in 1982. Gains were good during the first two grazing cycles but in August the animals refused to eat kochia. This resulted in a weight loss of more than three pounds per animal per day.

We at OSU do not recommend kochia as a planted forage crop. If it is available, it can be used for grazing or hay. Other forages can be more dependable under the same fertility program with fewer potential animal health problems.

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NO-TILL FORAGE ESTABLISHMENT

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Alfalfa acreage is increasing in Virginia. One of the primary concerns in establishing new stands of alfalfa and other forages is the threat of soil erosion while the new seeding is becoming established in a well-tilled seedbed. Resulting ruts and gullies damage equipment and are dangerous to equipment operators. In addition to conserving soil, no-till seedings conserve moisture already present in the seedbed. This, plus the dramatic reduction in water run-off, improves the water supply for the new seedlings. Less time and fuel are required to seed using no-till methods and rocks remain below the soil surface. Technology is now available to successfully establish forages without the need for tillage and preparation of a fine seedbed.

The new no-till procedures are becoming widely accepted by Virginia producers. A survey conducted in the fall of 1982 indicated that 82 sod seeders were available in that state, 80% of which were purchased during 1982. Approximately 2200 acres of alfalfa and 2300 acres of tall grass - clover were were seeded during 1982, which was the first season following the introduction of the no-till procedures.

NO-TILL REQUIREMENTS

Basic to successfully establishing new stands of forages by no-till methods is an understanding of the requirements for the procedure. Several "musts" are:

1. Living competition <u>must</u> be eliminated.
2. Heavy thatch and plant growth tall enough to shade the soil surface <u>must</u> be removed.
3. The seedling <u>must</u> be protected against a wide spectrum of insects.
4. Seed <u>must</u> be placed in the soil but no deeper than one inch.
5. Soil fertility <u>must</u> be medium to high with a pH of 6.4-6.7.

BASIC PROCEDURE

Removal of existing plant growth is accomplished by grazing and/or mowing. Elimination of competition from growing plants is dependent primarily upon herbicides. The following general "recipe" is a guideline to follow:

Apply 2,4-D if broadleaf weeds are present. After at least 10-14 days, apply Paraquat plus surfactant. Wait 14-20 days and make another application of Paraquat. Seed 15 lb of inoculated alfalfa seed per acre plus 10 lb of 10 G or 7 lb of 15 G granular Furadan per acre in the row with the seed.

INSECTICIDE

Furadan is a necessary part of the management package in order to protect the alfalfa seedling from insects. The specific insects or complex of them involved are not known and will vary with location and time of year. The granular form of Furadan must be placed into the soil in the row with the seed in order to meet label requirements. It is desirable to place the seed and Furadan in separate boxes on the seeder. However, Furadan can be mixed with the seed in the seedbox and separation will not occur as the seeder travels across the field. If the seeder being used has an agitator in the seedbox, separation of the Furadan is likely to occur. To prevent this separation, disengage the agitator.

FITTING INTO THE FORAGE SYSTEM

There are many different situations in forage systems where no-till alfalfa or other forage species can fit. In most cases, seeding as part of a normal crop rotation will aid in assuring adequate soil fertility and pH. There is concern that some producers may attempt to seed alfalfa in areas with shallow soils whose fertility and pH are too low to produce high yielding alfalfa. If soil fertility and/or pH is low, fertilizer and/or lime should be applied at least six months prior to seeding. Alfalfa should not be seeded into an old alfalfa stand. The field should not have had alfalfa growing in it for at least two years prior to seeding.

SEEDING IN SOD

No-till seeding into a perennial pasture or hay sod can be done effectively in either spring or fall using some variation of the "recipe". Of particular concern when seeding into a sod, especially in spring, is the lack of residual weed control. Herbicides used to suppress the sod do not control weeds that

germinate later and compete with the new alfalfa seedlings. Another concern is that occasionally Paraquat may not effectively suppress orchardgrass sods in spring. Unless the sod is primarily tall fescue, it is usually best to make the no-till seeding in August rather than in spring. Two applications of Paraquat on tall fescue after growth begins in spring are effective in suppressing the sod, permitting alfalfa to become established.

Fall seeding offers the advantage of less weed competition but insect pressure and soil moisture stress are usually greater than for spring seedings. An alternative to seeding into sod in spring is to graze or harvest hay until late July, then spray with two applications of Paraquat and sod-seed by mid-August. Other alternatives are to graze the sod in spring or take a spring hay cutting. Then spray the mowed or grazed sod with 1 qt. of Paraquat per acre and sod-seed a summer annual such as sorghum-sudangrass, millet, or perhaps grain sorghum-soybeans. After the summer annual is harvested for forage in early August, allow 4-8 inches of regrowth, apply 1-2 pt. of Paraquat per acre, and then seed no-till. Any regrowth by the summer annual grass or growth from weeds after the forage crop is seeded should be mowed if it reaches a height of 6-8 inches.

SEEDING INTO SMALL GRAIN

There are several ways to successfully seed alfalfa or other forages no-till into a small grain crop in the spring. One method is to spray the small grain with 1-2 pts. of Paraquat per acre when growth is 4-6 inches tall, then seed the alfalfa. The small grain will make regrowth which must be mowed when 5-6 inches tall to prevent smothering the alfalfa seedlings.

Forages may also be seeded without tillage into standing (8-10 inches tall) small grain prior to harvesting for silage. Rye harvested for silage in the boot stage will normally produce regrowth which must be mowed when 4-6 inches tall to reduce competition to the alfalfa seedlings. Barley and wheat cut at the dough stage will produce very little regrowth.

Forages may also be seeded into small grain stubble after a silage or grain harvest. If the silage harvest was made prior to dough stage, wait 5-10 days for regrowth to develop, then apply 1 pt. of Paraquat per acre to burn back the regrowth and kill weed seedlings. If the harvest was made at dough stage or later, apply 1 pt. of Paraquat per acre immediately and seed the alfalfa. Since grain harvest is quite late in the spring, waiting until early August to spray with 1-2 pints of Paraquat per acre and then seeding may be best. Volunteer small grain must be mowed after the seeding if it reaches a height of 5-7 inches. Another option is to apply Paraquat and seed a summer annual grass by the no-till method after the small grain crop is removed. The forage is then seeded

in August following the summer annual as discussed earlier.

SEEDING AFTER CORN

No-till planting of forages may also be successful in fields planted to corn the previous season. Preferably, the field would be planted to a small grain cover crop in the fall, but this is not absolutely necessary. Caution should be taken that residues from herbicides applied for the corn are not present in the spring. When the intention is to seed no-till in the spring following corn, short residual herbicides such as Bladex and Dual or Lasso should be used on the corn. The seeding can be done in mid-March but Paraquat may not be needed at that early date if the seedbed is free of weeds. Be sure the seedbed is free of even very small weeds before deciding not to apply Paraquat.

TECHNIQUES USING ELECTRONIC COMMUNICATIONS

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Those of us in extension have an opportunity to utilize modern communications and computer technology in our extension programs. Many of us are experiencing a period of tight budgets and often travel and printing funds are among the first areas targeted for reduction when belt tightening occurs. Yet, extension faces increasing accountability pressure to be more effective. Electronic extension delivery is one means of reaching more people at less cost than some of the more traditional means, namely printed extension reports and county level meetings. This does not mean printed materials and county meetings will be replaced entirely, only reduced or conducted differently.

My experience with electronic communications and computer technology comes largely from work with electronic marketing of agricultural commodities. Let me mention electronic marketing briefly. Electronic marketing involves using modern communications and data processing technology to market agricultural commodities. The objective is to create a centralized trading arena where all potential buyers and sellers can compete and finalize trades. Buyers and sellers use telephones or computer terminals to communicate with others in the market. Commodities are sold based on description, often by an unbiased or impartial third person. Thus, commodities frequently remain on the farm until the sale is completed and an acceptable price established.

The concept of electronic marketing is not new. Electronic marketing was first commercialized in 1961 when the Ontario Pork Producers Marketing Board began marketing slaughter hogs by teletype auction. The first commercial electronic market in the U.S. was a telephone auction for feeder pigs, begun by MFA Livestock Marketing Cooperative in Marshall, Missouri in 1965. The first application of computer marketing was in 1975. Plains Cotton Cooperative Association of Lubbock, Texas began marketing cotton over a computer network called TELCOT. Another application of electronic marketing uses video communications technology. The first commercial video auction began in Montana for

feeder cattle in 1976.

Now, how can we use the same electronic communications and computer technology in our extension programing that is used in marketing? I will discuss three broad types of electronic technology similar to three broad categories of electronic marketing. First, telephones; second, video tape and television; and third, computers.

USING TELEPHONES IN EXTENSION DELIVERY

All of us use the telephone in our extension programs for one-to-one contact with clientele. However, two offshoots can be especially useful. First is the conference telephone for telelecture or teleconference meetings and the second is the code-a-phone.

A conference telephone connection enables several people at one end of the connection to talk with several people at the other end of the connection. Individuals may each have a phone and be in separate locations or a group of people may use speakers and microphones with just one phone at each end of the connection.

An example of a telelecture as I use the term is when I am in my office and presenting extension information with an off-campus group at one location. An example of a teleconference as I use the term, is when I am in my office meeting with two or more off-campus groups at two or more locations. OSU agricultural economists regularly use teleconferences in presenting livestock and grain outlook and policy information. Telelectures or teleconferences usually need to be supplemented with overhead transparencies, slides, video tapes, or on-site demonstrations to be most effective. They are cost effective for small groups in distant locations from the campus or when you want to present the same material to several groups in several locations.

A code-a-phone is similar to a telephone answering service which all of us are familar with. At OSU we also use code-a-phones for livestock and grain outlook information. An audio tape recording is made and when clientele dial a specific phone number (it can be a regular long distance number or an 800 or a 900 long distance number) the audio tape is played automatically. This is particularly useful for keeping clientele informed on things that require periodic updates. An example for agronomists might be to use it in conjunction with plant pathologists and entomologists regarding insect and disease alerts and prevention or management solutions. It may be useful in terms of seed or fertilization rates, varieties and other factors given changing weather and economic conditions.

USING VIDEO TAPE AND TELEVISION IN EXTENSION DELIVERY

All of us probably have developed slide-tape sets in our extension work. While useful, slide-tape sets have limitations. Video tapes often overcome some of those limitations. Video tapes can be made with or without a great deal of planning and preparation. For example, you may have a specific crop field day in your state. Since several people cannot attend, selected segments of the program could be video taped while they are being presented and the tapes made available to groups of persons who did not attend. Even among those who are present, some participants comment that they would like to see or hear a given presentation again. Video tapes enable them to do that.

Planned video tapes may be made without the live audience and then the tapes can be used in an educational role. These tapes may require more preparation. Video tapes are especially useful because of the voice and visual editing capabilities. Video can be an important adjunct to a telelecture or a teleconference meeting as well as in-person meetings or conferences. Video tapes may also be edited for TV, either farm or news programs or educational television.

Two economists at OSU used talk-back television to conduct an in-service training session for county extension directors. Talk-back television enables viewers at several locations to watch on television those conducting the program. In our experience, the studio where the in-service program originated had two cameras. One was in front of us enabling us to use the blackboard or flipcharts. A second was overhead, and pointed toward the desktop to focus on papers, worksheets, demonstrations, or other materials on the desk or table. Slides, video tapes, or demonstrations, also can be used with this type of presentation. Dedicated phone lines enable participants to talk to the person or persons conducting the program or to people at other receiving locations. Our experience was mixed. We came away believing in the usefulness of talkback television, but we found that a practice session is desirable in order to effectively make use of visual aids.

Some states make effective use of educational television. Audience numbers are smaller compared to commercial television but time is more available. Therefore, specialists have an opportunity to delve fairly deeply into a given subject area which they cannot normally do in 1½-3 minutes time for personal interviews or video tapes on commercial television.

Video tape equipment, talk-back television and educational television have a high fixed cost. However, if costs are measured in terms of persons reached, their cost effectiveness can be argued convincingly.

USING COMPUTERS IN EXTENSION DELIVERY

This is truly the age of computers and we need to make the best possible use of this available technology. Already, many states have micro-computers in all their county extension offices. While part of the reason for this is for office management, there are a number of other potential uses for us as state specialists. One use is electronic mail. We can instantly send written information to area and county extension staff and thereby keep them up to date. We can send tabular and graphic material as well as word charts from which they can make overhead transparencies for telelectures and teleconference meetings. By combining electronic mail and word processing, we can tailor extension information to whatever part of the state or specific commodity is appropriate. For example, variety tests may be tailored to specific parts of the state based on the annual precipitation levels and soil types.

In a similar manner, state specialists can receive reports from farmers and extension staff by electronic mail. For example, area or county extension staff might report such things as planting or harvesting progress, and rainfall and pasture conditions. We then can use such information in timely educational programs. Such timeliness may enable us to identify the teachable moment and capitalize on it.

Perhaps because of my economic bias, one of the greatest advantages of micro-computers is their usefulness in making more accurate, timely, complex, and complete management decisions. Complex interdisciplinary decision models can be developed and made readily available to teach producers fundamental agronomic and economic principles. You can probably think of better applications than I can, but three examples of decision aids might include: (1) studying the interrelationship between weather, soil type, and other factors to determine the desirability of low-till versus conventional planting; (2) studying the relationships between planting time, weather, soil type, and of selected plant varieties to fertilizers, to determine optimum fertilization amounts and timing; and (3) studying the trade-off between possible insect and disease damage and yield loss versus cost of control measures, to determine the type and amount of insect control for various crops.

CONCLUSIONS

Modern communication and computer technology is changing the role of extension. No longer can we continue doing what has worked well for us in the past. Our clientele is becoming more sophisticated and demanding more from extension, despite not providing us with many resources as in the past. The challenge is clear, we must adapt our extension programs and delivery systems to the technology or lose clientele support.

COMPUTERIZED HAY MARKETING

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Alfalfa is the only major crop in the United States with no organized marketing system. In Oklahoma, alfalfa is commonly grown for stables and dairies throughout Oklahoma and surrounding states. A large proportion of Oklahoma alfalfa is raised and sold to other producers. This transaction has historically been a risky and often non-profitable undertaking for both buyers and sellers. Growers have often had insufficient information about potential buyers, their hay needs, and how much they are willing to pay. Buyers lack information about where and how much hay is for sale, its quality and how much growers want for it. Thus, a more efficient marketing system would result in (1) better information for both buyers and seller on hay demands and supplies, and (2) better market information on hay prices based on quality factors. Haymarket, a computerized alfalfa marketing system, is designed to bring buyers and sellers together.

The Oklahoma Alfalfa Hay and Seed Association (OAH&SA) is the sponsoring organization for Haymarket. Haymarket is designed to serve two purposes: (1) Locator Service and (2) First Evaluation. From the Haymarket information, buyers will know the location of alfalfa and its relative quality. An unbiased third party grader will visually grade the alfalfa for maturity (3 catagories), foreign material (type and amount), and color (4 catagories). Random core samples are also taken for percent crude protein and moisture. The visual evaluation attempts to answer some of the questions a buyer would ask over the phone. All graders must be approved by the OAH&SA Board of Directors and complete training once/year.

Information currently mailed to over 500 potential buyers includes: grower name, address, and phone numbers, harvest package, cutting, tons, percent protein and moisture, sample date, foreign matter (type and amount), maturity, color, and

comments. Information will also be available in a dial-up basis by potential buyers using a computer terminal. Cost for growers is $10/lot (1 cutting off 1 field) plus $6 for chemical analysis.

Receptivity from both buyers and sellers has been extremely favorable. Both buyers and sellers see opportunity to reduce their costs and increase profitable marketing. Potential benefits to producers could be as high as $10/ton.

EFFECT OF FERTILIZER APPLICATION AND GRAZING MANAGEMENT ON GRAZED NEW ZEALAND HILL COUNTRY

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INTRODUCTION

Approximately 13 million ha, or 50%, of New Zealand's area is pastoral, supporting populations of 2.9 million dairy cattle, 5 million beef cattle, and 70 million sheep. Some 70% of export income is from sale of agricultural, horticultural, and silvicultural products, and 85% of this is from wool, meat, and dairy products.

About 4.5 million ha is classed as hill country (Brougham and Grant 1976), including land with soils from volcanic to sedimentary origin, annual rainfall from 350 to 2,500 mm, and altitude from sea level to 1,000 m. Pastures in hill country are "permanent," are grazed year-round, and emphasis is on minimum use of conserved feed. Primary limitations to pasture production are water supply in the warm season, and soil N supply at all times other than during drought. Irrigation is rarely practiced; the major N input to the pastoral N cycle is N fixation by legumes, and fertilizer N is generally used only to boost pasture growth to overcome seasonal feed deficiencies.

In hill country, farm income is generated mainly from sales of wool (43%), sheep (29%), and beef cattle (24%) (NZMWBES 1983).

Profitability per hectare is a major determinant in making management decisions. Increases in per hectare productivity and profitability are sought through attention to fertilizer application regime, stocking rate, grazing management, genetic merit of livestock, introduction of superior pasture cultivars/species, and control of brush weeds.

The trial described here was initiated to investigate influences of two of the above variables, fertilizer application and grazing management, on low fertility, "moist" hill country in the North Island of New Zealand.

EXPERIMENTAL PROCEDURES

The trial is in progress currently, although with modified experimental treatments, at "Ballantrae," a hill country research area of Grasslands Division, DSIR, located near Palmerston North at latitude 40°S, and 125-350 m altitude. Average annual rainfall is about 1,280 mm, relatively evenly distributed, and average (max. + min./2) 1.2 m air temperature is 16.1°C in February and 7.2°C in July. Soils are derived from Tertiary sediments.

Ninety-nine ha of dissected hill country was divided into 10 farmlets. Treatments were two fertilizer levels (LF = 11 kg P ha^{-1} yr^{-1} as superphosphate, HF = 57 kg P ha^{-1} yr^{-1} plus lime) and three grazing managements [rotationally grazed Angus breeding cows (RGC); rotationally grazed breeding ewes (RGS); set stocked ewes (SSS)], in factorial arrangement with replication (3X) of SSS at both fertilizer levels. Legume (white, red, and subterranean clovers, and big trefoil) seed was oversown in order to ensure a responsive pasture legume component. Only small amounts of fertilizer had been applied in previous years, and soil available P status was very low.

RGC and RGS animals were allocated a new area of pasture three times each week; rotation length was longest in winter (55-70 days) and shortest in spring (21-25 days). "Set stocking" was continuous grazing at constant stocking rate throughout the year, apart from natural increase which occurred in all grazing managements. Young stock were removed from all farmlets at weaning. Stocking rate was the same across grazing managements within each fertilizer level, and was higher for the HF than the LF level. Stocking rate was increased in annual increments from 6.5 (in 1975) to 12.0 (in 1981) stock units [(SU) 1 SU = 1 ewe plus lamb(s) to weaning; 1 cow plus calf to weaning = 6 SU] ha^{-1} on LF farmlets, and from 8.8 to 16.1 SU ha^{-1} on HF farmlets. Increase in stocking rate was designed to maintain similar grazing pressure as pasture production increased in response to treatments. Lambert et al. (1983) give more details of experimental design and procedure.

Measurements of pasture and soil parameters, and of animal performance, were made during the period considered here--1975 to 1982.

RESULTS AND DISCUSSION

Pastures

Pasture production, measured by a "trim technique" using grazing exclosures, was more strongly influenced by fertilizer application than grazing management treatments (Table 1). Response in the first year was only 9% in favor of HF, but subsequently was 21-50%. This lag occurred while legumes responded to fertilizer application, and soil N availability was increased as a result of cycling of symbiotically fixed N through animal excreta and pasture decay cycles. Small-plot trials (Lambert and Grant 1980) indicated that fertilizer level differences were due predominantly to the superphosphate rather than the lime component of the HF regime.

Pasture production was similar on sheep-grazed treatments, but over the 6-year period an average depression of about 9% occurred on RGC farmlets. This was probably a consequence of treading damage while soils were very wet in winter and early spring. Herbage mass measurements, coupled with estimates of animal intake, indicated that RGS pastures actually had 20% higher growth rates in spring and early summer, or about 12% on an annual basis, than did SSS pastures. It appeared that the trim technique we used overestimated production in grazed SSS pastures more than in grazed RGS pastures (Field et al. 1981). This was probably a result of reproductive tillers being more frequently defoliated in SSS than in RGS pastures (Clark et al. 1982). As a consequence, the reproductive surge which occurs during spring and early summer was depressed more in SSS than RGS pastures.

Botanical composition was influenced by treatments (Table 1). HF pastures had higher ryegrass and legume and lower low-fertility-tolerant (LFT) grass content than LF pastures. RGC pastures were more legume- and ryegrass-dominant and had lower LFT grass content than sheep-grazed pastures. The lower density of the RGC pastures probably favored legume growth, and treading damage gave ryegrass a competitive advantage over the more susceptible LFT grasses.

Pasture structure was influenced by grazing management. Density was reduced by rotational grazing, especially with cattle (Table 1), and the fewer plant parts tended to be proportionately larger in these pastures. Vertical distribution of biomass differed for the relatively prostrate SSS and erect rotationally grazed pastures, e.g., 55% of above-ground biomass was below 10 mm in SSS pastures, but only 35% in rotationally grazed pastures. This difference could make rotationally grazed pastures more susceptible to damage from overgrazing.

Table 1.--Pasture characteristics. Averages for 1975-81.

	Fertilizer		Management		
	LF	HF	RGC	RGS	SSS
Pasture production (kg DM ha^{-1} yr^{-1})	8910	11640	9580	10600	10390
Botanical composition (%)					
Legumes	13	17	19	13	13
Ryegrass	18	25	28	22	18
LFT grasses[1]	49	19	36	47	50
Pasture structure					
Density (units m^{-2} x 10^3)			15	23	28
Grass tiller wgt. (mg)			5.6	4.1	3.4
White clover leaf size (cm^2 $leaf^{-1}$)			1.1	0.6	0.6

[1]Low-fertility-tolerant grasses: mainly bentgrass (*Agrostis* spp.), sweet vernal (*Anthoxanthum odoratum*), crested dogstail (*Cynosurus cristatus*).

Nutrient Cycling

N fixation, measured by the acetylene reduction method, was approximately 30 kg N ha^{-1} yr^{-1} in 1974/75 (Grant and Lambert 1979), before treatments were imposed. In 1976/77 N fixation had increased to 70 and 120 in sheep-grazed LF and HF pastures, respectively, and 110 and 250 in RGC-LF and RGC-HF pastures, respectively. Available N status of soils (to 75 mm depth), assessed by a modified stress labile N (Ayanaba et al. 1976) method in 1980, was higher in HF (69 kg N ha^{-1}) than LF (55 kg N ha^{-1}) soils. Although of low statistical significance ($P = 0.25$), RGC soils had a larger pool of labile N (71 kg N ha^{-1}) than soils under sheep grazing (59 kg N ha^{-1}). These values are in accord with measured differences in N fixation. In years 2-5 of the trial, legume content decreased at both fertilizer levels; this appeared to be associated with an increase in soil N availability and resultant increased competitiveness of associated grasses.

Earthworm populations, estimated in 1979 using a formalin-extraction method, were 24% higher in HF than LF soils, presumably a result of increased organic cycling.

Table 2.--Average animal production (kg/ha) during 1975-82.

	Fertilizer		Management		
	LF	HF	RGC	RGS	SSS
Wool	53	69	--	61	61
Lamb liveweight	215	297	--	244	268
Calf liveweight	220	279	250	--	--

Animal Production

HF sheep-grazed treatments yielded 31% more wool ha^{-1} and 38% more weaned lamb liveweight ha^{-1} than LF sheep-grazed treatments (Table 2). A similar difference between fertilizer levels existed for calf production from RGC farmlets (27%). These increased production levels were almost entirely a consequence of the higher stocking rates maintained on the HF farmlets in order to ensure similar utilization of pasture across fertilizer levels (Clark and Lambert 1982).

Wool production was not different for RGS and SSS treatments (Table 2). Lamb production tended to be greater from SSS farmlets in early years of the trial, at lower stocking rates. In 1981/82, at a much higher stocking rate than that employed by commercial farmers, RGS farmlets had higher lamb production.

Pasture/Animal Interface

In hill country farming, the farmer attempts to match feed supply and animal requirement, without recourse to large inputs of conserved feed. Figure 1 illustrates typical pasture growth and animal requirement curves in our LF sheep-grazed systems, if stocked at 10 SU ha^{-1}. Mating was in early April, lambing in September, and weaning in early January. Comparison of the two curves indicates that animal requirements exceeded pasture growth during mid-July to mid-September, and growth exceeded requirements at other times. Two large buffers operated to smooth these inequalities:

(i) Animal intake was restricted to below maintenance during the period of low pasture growth, resulting in weight loss. Weight gain occurred later in the year when pasture growth rates were higher. Average annual minimum and maximum liveweights for our experimental animals were 46.1 and 53.3 kg for ewes, and 406 and 473 kg for cows, i.e., an annual weight loss of 17% and 14%, respectively, from maximum to minimum.

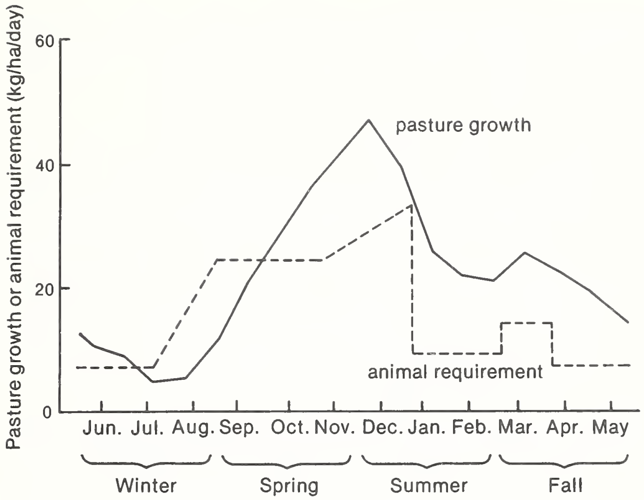

Figure 1.--Pasture growth and animal requirements in low fertilizer, sheep-grazed systems stocked at 10 SU ha^{-1}.

(ii) Mean pasture availability varied throughout the year, from about 2,500 kg DM ha^{-1} above ground level during summer to about 1,100 kg DM ha^{-1} at the end of winter, prior to onset of rapid spring growth.

Despite these buffers, critically low pasture availability can occur in winter or during drought, and in order to prevent excessive stock losses farmers use fertilizer N to boost cool-season pasture growth, or supplement with conserved feed. Rotational grazing through the winter makes it easier to carry autumn-grown pasture forward to the late winter when feed supplies are low.

Excessively high pasture availability can be a problem in wet summers. High levels of dead and senescing plant material limit the ability of animals to select a high-quality diet.

It is our belief that a flexible approach to grazing management can be advantageous. During periods of low pasture availability, growth can be enhanced by rotational grazing. We also believe that when growth conditions are favorable, and pasture availability reaches levels which do not restrict animal intake, then set stocking can maintain quality of pastures at a higher level than if rotational grazing was implemented. This increase in quality may have to be balanced against decreased pasture productivity. However, where major

nutrient-supply limitations to legume growth exist in grass-legume pastures, alleviation of these limitations will probably elicit far greater responses in animal production than will sophistication of grazing management.

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RECENT PROGRESS IN FORAGE PRODUCTION AND UTILIZATION IN SCOTLAND

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INTRODUCTION

The production and utilization of forage, both indigenous and sown, from hill land has been one of the most important areas of research since the Hill Farming Research Organization was established in 1954. Early studies examined the ecological status of the indigenous hill vegetation, its origin and its relationship with soil type, and with grazing and burning managements. Since then work has been carried out on the establishment and maintenance of sown pastures, particularly the role played by white clover, on the improvement of utilization of hill and upland swards by grazing animals and on the effects of utilization by grazing animals on growth and production of hill pasture, among a very large number of research activities.

THE INDIGENOUS VEGETATION AND LIMITATIONS TO ITS PRODUCTION

Table 1 summarizes the general relationships between the soils and the main vegetation types of the hill. The groupings are divided on the basis of soil drainage and soil acidity, with the emphasis on agricultural importance. On soils with a pH above 5.3 (mull soils) the vegetation is a high grade *Agrostis-Festuca* grassland with a large number of forbs and most importantly with white clover present. Grazing pressures are high and nutrient turnovers and decomposition processes are rapid. On soils between pH 4.5 and 5.0 species poor *Agrostis-Festuca* grasslands are found; clover is absent, decomposition is slower and humus tends to build up. On still more acidic sites with pH of less than 4.5 (mor soils) shrub or grass heath may occur depending on past burning or grazing history. The dominant species are those that are little grazed such as *Nardus stricta* and *Molinia caerulea* and humus begins to build up as peat. On the most poorly drained sites acid peat bogs occur.

Table 1. Summary of the main soil and vegetation types of the Scottish hills.

Soil	pH	Vegetation type
Brown earth freely drained	5.3 - 6.0	*Agrostis-Festuca* grassland high grade or spp. rich
Gleys poorly drained	5.3 - 6.0	As above with wet-land spp *Carex*, *Juncus*
Brown earth freely drained	4.5 - 5.2	*Festuca-Agrostis* grassland low grade or spp. poor
Gleys poorly drained	4.5 - 5.2	As above *Nardus* and wet-land spp. *Carex*, *Juncus*
Podsols Peaty podsols freely drained	4.0 - 4.5	*Nardus* or *Deschampsia/Festuca* grass heath or *Calluna* shrub heath
Peaty gleys poorly drained	4.0 - 4.5	*Molinia* grass heath or *Calluna/Molinia* heath
Deep blanket peat poorly drained	3.5 - 4.0	*Trichophorum/Eriophorum/Calluna* bog

At the highest elevations climatic factors impose overriding limitations on herbage production, but elsewhere on the hill the interactions between climate, altitude, soil and vegetation variously limit pasture production, and thus potential production varies considerably from site to site. As altitude increases, so temperatures decline and the length of the growing season is reduced. Delay to the start of growth in the spring can be a considerable problem particularly since the demands of the lambing and lactating ewe are at a peak.

Problems of soil wetness combined with soil acidity are of considerable importance in determining herbage production. Decomposition rate is largely controlled by soil acidity and

this may be the limiting factor to the cycling of nutrients in the soil-plant-animal system (Floate, 1970).

Limitations to hill land pasture production are due to five groups of factors - climate, site, soil, vegetation and management (HFRO, 1979). Some, such as climate and site, are permanent; others can be corrected at a greater or lesser cost. Most recent work has concentrated on reducing the limitations due to soil, vegetation and management. Limitations to pasture use are two-fold: where the quality of the herbage is good, the quantity of pasture and its regrowth capabilities are limiting; where quality is low, the extent and pattern of pasture use is limited by the nutritional penalties to the grazing animal. Only the acid grassland falls into the former category; the use of all other communities is limited by the quality of the herbage.

Much of the early work on the improvement of indigenous pasture, which highlighted the shortness of the growing season of hill pasture, together with a better understanding of the nutrional requirements of hill sheep led eventually to the formulation of the two-pasture system (Eadie, 1970). The two-pasture system requires that a small area of ground (1 ha/15 ewes) be reseeded and managed alongside unimproved hill ground. The improved pasture is used to provide feed of improved quality during the critical periods of lactation, premating and mating. A consequence of the provision of improved pasture is that pasture utilization improves overall and generally allows for an increase in stock number. A certain degree of supplementation with hay and/or concentrates is necessary during late pregnancy.

As the two-pasture system continued to be developed, various problem areas were highlighted as requiring further basic research. They included the important role of clover in the improved pasture and the need to maintain the clover population, the improvement of utilization of indigenous pasture by both cattle and sheep, and the effects of utilization by sheep and cattle on the growth and production of improved hill pasture.

THE ROLE OF CLOVER IN IMPROVED HILL PASTURES

The availability of nitrogen is a key factor in the productivity of hill pastures. Nitrogen, unlike lime and phosphate, is rapidly lost from the soil and thus requires repeated application. Hill pastures are frequently difficult to reach and application of fertilizer is becoming increasingly expensive. Newbould and Haystead (1978) have discussed the role of white clover in hill pasture and the biological reasons for its importance. Early work indicated that the appropriate strains of *Rhizobium* are not always present in all hill soils or in sufficient numbers to form an effective symbiosis (Holding and King, 1963; Singer, Holding and King, 1964). More recent

studies (HFRO Biennial Report, 1982) have examined the relationships between mycorrhiza and white clover, particularly since phosphorus uptake is thought to be increased with effective mycorrhiza/ white clover symbiosis and since once soil acidity has been corrected phosphorus is the nutrient most likely to restrict clover growth. The results so far have indicated that as with *Rhizobium*/clover interactions some strains may be more beneficial than others. Other basic research is being carried out on the rate of nitrogen fixation and the influence of defoliation on the rate of fixation and on the overall nitrogen economy of the clover plant. Results indicate that the rate of fixation is influenced by the degree of *Rhizobium*/white clover association and by the supply of photosynthate to the roots. Post-defoliation leaves and growing shoots are priority sinks for nitrogen with most of this nitrogen coming from already assimilated nitrogen, mainly from stolon material. Evidence for the transfer of nitrogen from white clover to grass is somewhat inconclusive with ^{15}N enrichments of grass in pure and mixed swards differing only slightly (HFRO Biennial Report, 1982).

THE IMPROVEMENT OF UTILIZATION OF INDIGENOUS HILL PLANT COMMUNITIES

Investigations into the improvement of utilization of indigenous hill plant communities began in 1977 and the first phase, designed to study nutrient intake, ingestive behaviour and diet selection ended in 1980. A second phase will examine the effect of controlled grazing on the botanical composition of these communities, their herbage production and nutritive value, and the nutrient intake of animals grazing them (HFRO Biennial Report, 1982). Prior to this study the only available information related to Calluna-dominant heather moor (Grant *et al.*, 1978; Milne *et al.*, 1979) and *Agrostis-Festuca* grassland (Eadie, 1967; Nicholson, 1967).

Measurements were made on six communities-

1. *Agrostis/Festuca* grassland.
2. *Nardus stricta* - dominant dry grass heath.
3. *Molinia caerulea* - dominant wet grass heath.
4. *Calluna vulgaris* - dominant heather moor.
5. *Calluna/Eriophorum/Trichophorum* blanket bog.
6. Perennial ryegrass (*Lolium perenne*) sown pasture.

The perennial ryegrass pasture was included to act as a link with other studies on sown swards at H.F.R.O. and elsewhere.

Detailed observations on herbage intake, diet digestibility, intake per bite, rate of biting and grazing time were made on cattle and sheep grazing together on the grass and grass heath communities (Forbes, 1982). Detailed studies were made at the same time on associations between sward structure, botanical composition, ingestive behaviour, diet selection and herbage

intake. On the indigenous swards the cattle and sheep selected diets of similar organic matter digestibility except in the spring and autumn on short swards where the sheep obtained diets 5 to 12 units of digestibility higher than those of the cattle. Intake per bite was found to be the major determinant of daily herbage intake in both species, and was influenced primarily by sward height. Where intake per bite declined due to declining sward height, rate of biting increased (Fig. 1).

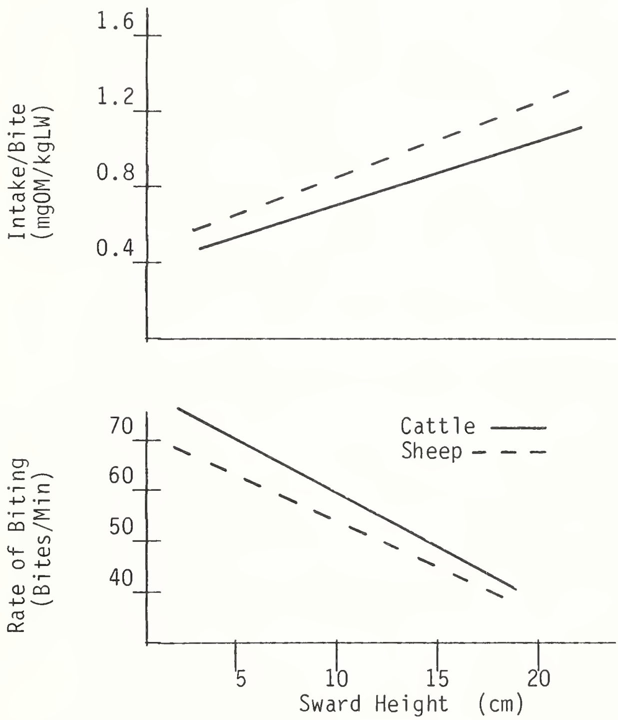

Figure 1. The relationships between intake per bite, rates of biting and sward height (Forbes 1982).

Increases in grazing time occurred where intake per bite was particularly low, but the response was not consistent. The cattle responded to increases in sward bulk density by increasing rate of biting; the sheep increased grazing time. The cattle responded to an increasing leaf: stem ratio by decreasing rate of biting; the sheep reduced grazing time. Very low intakes per bite in the early spring on short swards, where the digestibility of the diet selected was low, due to a low green to dead ratio, led to digestible organic matter intakes by the cattle that were barely adequate for maintenance.

The cattle consistently ate higher proportions of green flower heads and stems whilst the sheep consistently ate higher proportions of forbs. To obtain these diets the cattle grazed the surface horizons whilst the sheep grazed the base of the sward. On short swards in spring the cattle were unable to avoid eating a higher proportion of dead herbage than the sheep.

The cattle and sheep altered their ingestive behaviour in a consistent manner across the range of swards. Changes in diet selection varied to a greater extent within season than within swards. The selective ability of the sheep allowed them to maintain the nutrient concentration of their diets. The cattle modified their grazing behaviour to allow them to maximize nutrient intake, particularly in the summer months. The different grazing strategies of the cattle and sheep allowed them to be complementary rather than competitive grazers in the summer months, and since the cattle grazed the surface horizons this study confirmed the value of using cattle to manage the vegetation in the summer months at no disadvantage to them and some large advantage to the sheep.

EFFECTS OF UTILIZATION BY GRAZING HILL SHEEP AND BEEF CATTLE ON THE GROWTH AND PRODUCTION OF HILL PASTURE

This work was undertaken because, though cutting and intermittent grazing studies have shown that temperate pasture production can be increased by controlled grazing (Brougham, 1959 and 1960; Jameson, 1963; Davidson, 1969), net herbage accumulation (NHA) appears to be remarkably insensitive to variations in grazing management (Hodgson and Wade, 1978). In most grazing trials, the estimates of herbage production, which in reality are estimates of net change in herbage mass over time, are inadequate for calculation or interpretation of the dynamics of herbage growth and utilization. A series of experiments by Bircham (1981), and Bircham and Hodgson (in press a and b) and others (Grant et al., 1981; Grant et al., in press; Arosteguy, 1982), were conducted that examined rates of herbage growth, and losses due to herbage consumption and senescence and decomposition, in order to determine net herbage accumulation and the efficiency of herbage utilization.

The results of four field trials have shown consistently that rates of herbage production per ha are greatest when swards are maintained between 1000 and 1700 kg OM/ha with rapid declines at lower levels but relatively small changes above 1000-1200 kg OM/ha. Figure 2 shows the results of a series of experiments in which simple ryegrass/white clover swards where maintained at different herbage masses throughout the grazing season. The relative insensitivity of net herbage production to wide range of continuous stocking treatments is a consequence of rapid adaptive changes in sward characteristics. As herbage mass is reduced individual tiller size is reduced but

tiller population density increases up to levels as high as 60,000 tillers/m^2 (Fig. 3). Tiller population densities are lower on cattle-grazed compared with sheep-grazed swards leading to lower herbage growth and net production on the cattle-grazed swards later in the season.

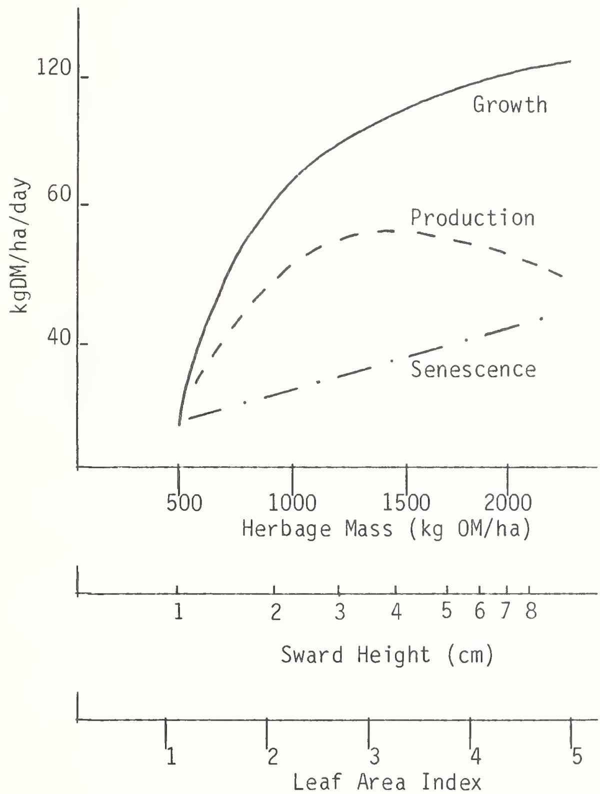

Figure 2. The influence of variations in herbage mass on rates of herbage growth, senescence and net production in swards continuously grazed by sheep. The associations between herbage mass, sward height and leaf area index for also shown. (Bircham and Hodgson 1982)

The results indicate that there is little advantage to be gained in terms of net herbage production, or in production of weaned lamb by maintaining continuously stocked swards of a herbage mass in excess of 1200-1500 kg/OM/ha (Fig. 4). Further work is being carried out in order to define the optima for cattle and mixed grazing systems.

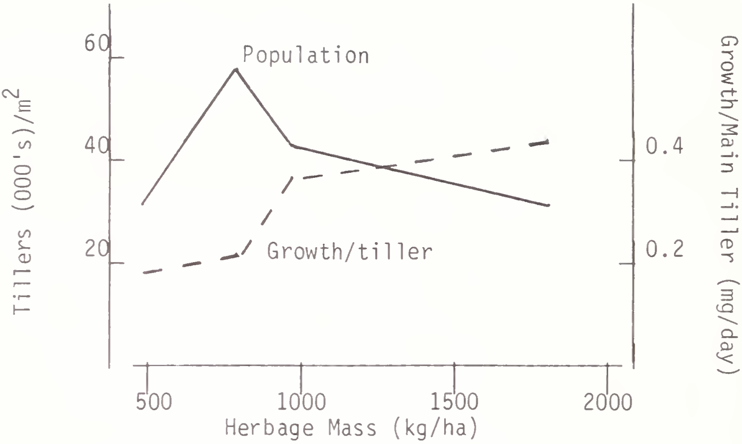

Figure 3. The influence of herbage mass on tiller population density and growth per tiller in a sward continuously grazed by sheep. (Bircham 1981)

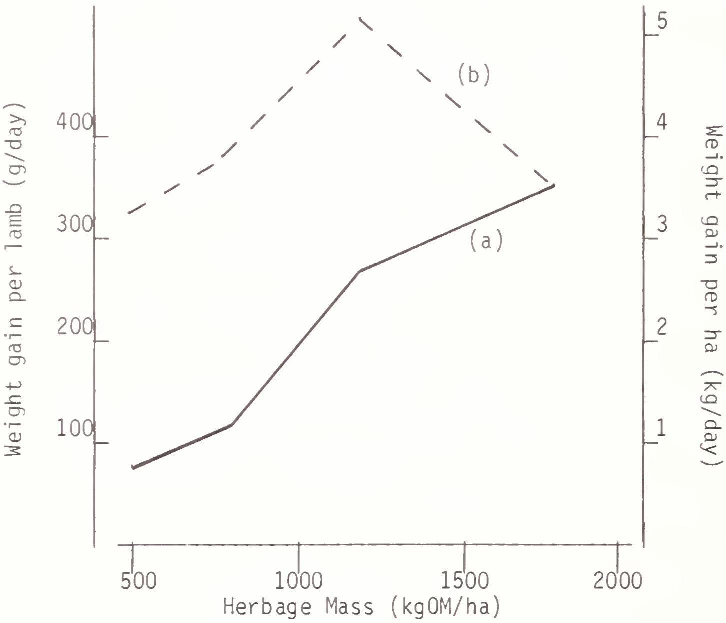

Figure 4. The influence of herbage mass maintained under continuous stocking management in (a) LWG of individual lambs and (b) lamb production per ha per day. (from Bircham 1981)

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